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ABSTRACT

The document is one of seven volumes of instructional materials developed around a cluster of Transportation Industries. Primarily technical in focus, they are designed to be used in a cluster-concept program and to integrate with a regular General Education Development (G.E.D.) program so that students may attain an employable skill level and a general academic background simultaneously. They provide basic skills necessary to enter a number of occupations in the Transportation cluster rather than an indepth development of skill in any one occupation. The volume contains approximately 120 hours of instruction in Pneumatics, Hydraulics, and Fluids and consists of 20 instructional units, each having one or more specific lessons. Each unit is designed for six hours, or one day, of instruction: three hours of technical laboratory instruction and three hours of related study in science, math, communications, and social studies. In most cases,there is only one lesson per unit. The units offer the instructor the essential materials: the aims (both in technical areas and in the four general education areas), instructional aids, topical outline and activities, suggested time sequence, evaluation guidelines, summary, and references. A selected bibliography concludes the volume. (Author/AJ)

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Commonwealth of Pennsylvania

Department of Justice

Bureau of Correction

VOCATIONAL EDUCATION
PROGRAM OF STUDIES

Elementary, Secondary Education Act

Title I

TRANSPORTATION CLUSTER

VOLUME V

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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January 1, 1971

Pennsylvania Bureau of Correction

Harry A. Snyder

Director of Education

INTRODUCTION

The following information comprises one of seven volumes of instructional materials developed around a cluster of Transportation Industries and Occupations. These instructional materials are primarily technical in focus but are written to be used in a cluster concept program as part of an integrated curriculum.

The materials are aimed at preparing students with basic skills necessary to enter a number of occupations in industries within the Transportation cluster rather than providing an in-depth development of skill in any one occupation.

Each volume contains approximately one hundred twenty hours of instruction (about one month of study) and consists of twenty instructional units each having one or more specific lessons. Each unit is designed for six hours of instruction (three hours of technical laboratory experiences and three hours of related study in science, math, communications and social studies) but may be varied at the instructor's discretion.

The seven volumes or cluster areas in the series are:

Volume I - Automotive Services I
II - Automotive Services II
III - Small Power Sources
IV - Driver Training
V - Pneumatics, Hydraulics and Fluidics
VI - Farm and Earthmoving Equipment
VII - Transportation Systems

Students in the Transportation cluster should be introduced to the technical and integrated content through several methods closely related to the industrial structure. Among these are line production and assembly, group projects, experimentation, unit studies and independent study. Team teaching techniques should be employed between the academic specialist and the technical work within one cluster, a student could elect to specialist and coordinators.

It is recommended that an orientation program be offered students to familiarize them with the cluster areas available so they may select one they wish to pursue. The cluster instruction is designed to integrate with the regular G. E. D. program so that students may receive an employable level of skill and a general academic background simultaneously.

As students select the technical cluster areas they wish to study, they should have the option to move through the G. E. D. content at their own speed using programmed instructional materials, instructional television, computer assisted instruction and other individualized learning techniques. Technical and integrated concepts are introduced each day by the specialists involved.

After completion of one or more months of study within another cluster providing, of course, this transfer is agreeable with the counselors, coordinators and instructors involved.

Lessons have been identified in the units. In most cases, however, there is only one lesson since each unit is limited to one day or six hours of instruction. The units offer the instructor the essential materials, vis-a-vis the aims, instructional aids, topical outline and activities, suggested time sequence, evaluation guidelines, summary and references. The primary and supplemental references are directly related to the topics and are important to the instructors. A selected bibliography is attached at the end of each volume as recommended additional sources of information.

Pagination of the units in this volume has been identified by cluster (T), volume (I, II, etc.), unit (1, 2, etc.) and page (.1, .2, .3, etc.) within each unit.

TABLE OF CONTENTS

Unit		Page
1	The Development and Application of Fluid Power	T-V- 1.1
2	Introduction to Hydraulics	T-V- 2.1
3, 4	Fundamental Physical Laws and Their Application to Fluid Power	T-V-3.1 & T-V- 4.1
5	Hydraulic Fluids, Reservoirs, Valves, Tubing and Fittings	T-V- 5.1
6	Hydraulic Pumps	T-V- 6.1
7	Basic Hydraulics . . . Pressure Controls	T-V- 7.1
8	Directional Control Valves	T-V- 8.1
9	Linear Actuators and Accumulators	T-V- 9.1
10	Flow Control Valves	T-V-10.1
11	Fluid Motors and Related Components	T-V-11.1
12	Mobile and Industrial Hydraulic Circuitry	T-V-12.1
13	Introduction to Pneumatics	T-V-13.1
14	Applied Physics as Related to Pneumatics	T-V-14.1
15	Pneumatic Pressure Sources	T-V-15.1
16	Pneumatic Cylinders	T-V-16.1
17	Pneumatic Valves	T-V-17.1
18	Practical Application of Pneumatic Devices	T-V-18.1
19	Pneumatic Directional Control Devices	T-V-19.1
20	Fluidics (Fluid Amplifiers)	T-V-20.1
BIBLIOGRAPHY		t-V-i

INSTRUCTOR'S UNIT PLAN

Unit 1
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **The Development and Application of Fluid Power**

AIM: To acquaint students with the development and application of fluid power.

INSTRUCTIONAL AIDS:

Film - **Compressed Air and Gas,** 55 Public Square, Cleveland, Ohio: Compressed Air & Gas Institute (17 minutes, 16 mm).

Film - **Compressed Air Power** #2935, 910 Penn Ave., Pittsburgh, Pa.: Modern Talking Picture Service (17 minutes, 16 mm).

Film - **Controlled Power,** Troy, Mich. 48084: Vickers Hydraulics, Sperry Rand Corporation (22 minutes, 16 mm).

EQUIPMENT:

16 mm projector, screen, Scott Fluid Power Educational System and Electromatic Educational Program.

PRIMARY REFERENCES:

1) Hedges, Charles S., **Industrial Fluid Power, Volumes I, II and III,** 2010 Shea Road, Dallas, Texas 75235: Womack Machine Supply Company, 1965-66.

2) **Scott Fluid Power Education System,** 1400 S. W. 8th Street, Pompano Beach, Fla. 33060: Scott Engineering Corporation, 1967.

3) Southeastern Engineering Co., **Electromatic Education Program,** P. O. Box 7398, Nashville, Tenn. 37210.

4) Stewart, Harry L., **Practical Guide to Fluid Power, Indianapolis:** The Howard W. Sams Company, Inc., 1966.

I. INTRODUCTION and MOTIVATION

Bulletin boards display illustrating fluid power use. Introduction to fluid power applications in related areas. Introduce film and indicate important aspects for observation.

II. PRESENTATION OF INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Definitions 1. Fluid 2. Fluid power systems	1. A fluid is any material which is capable of flowing; it may be either gas or liquid. 2. A fluid power system generates, transmits and controls the application of power through the use of pressurized fluids within an enclosed circuit.	1. What is a fluid? 2. Pressurized fluids . . . effects and reactions.
B. History of fluid power	1. Fluid power began when Pascal's Law was discovered in 1650. 2. Steam-driven water pumps power machinery in 1850's. 3. A hydraulic system was developed elevating and controlling battleship guns on U.S.S. Virginia in 1906. 4. Hydraulic system includes reservior pumps, controls, accelerators and is self-contained. 5. Over 90 percent of all machine tools are controlled or operated with fluid power.	
C. Advantages of fluid power	1. Flexibility in control of machines. 2. Efficient method of multiplying forces. 3. Provides constant torque at variable speeds 4. Gives fast response to controls and can amplify large forces. 5. Provides automatic lubrication. 6. Economical, efficient and dependable. 7. Gives predictable performance.	1. Laws of friction and their effect on fluid pressure.
D. Hydraulic and pneumatic systems	1. Hydraulic systems use oil and pneumatic systems use air. 2. A simple fluid system contains an oil pump or compressor, a piston or rotating member driven by the fluid and piping and valve devices to control the flow of the fluid.	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Calculation of psi.	1. Set up and operate visual aids equipment. 2. Fluid power system terminology.	
1. Cost increase of equipment thru the years. 2. Salaries and wages.		1. History of fluid power in the development of industrial America.
1. Calculations of ratios. 2. Measurement: metric and linear.	1. Review ways of locating information: a. Table of Contents b. Index c. Card Catalog d. Etc. 2. Locate information from fluid power directory.	1. Current use of fluid power equipment in everyday living, industry and armed services. 2. Effects on standard of living.

II. PRESENTATION OF INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
E. Applications	1. Automatic hoist. 2. Farm machinery. 3. Earth movers. 4. Space program. 5. Concrete mixing. 6. Rivet guns. 7. Power steering and brakes. 8. Manufacturing. 9. Numerical control. 10. Instrumentation. 11. Fluidic amplifiers.	
F. Principles of fluid power	1. Pascal's Law . . . pressure setup in a liquid or gas exerts a force equally in all directions. The pressure vector is perpendicular to all the containing surfaces. 2. Boyle's Law . . . if the temperature on a gas remains constant the volume will vary inversely with the pressure. 3. Charles' Law is the relationship between the varying of volume and temperature directly if the pressure is held constant.	1. Demonstrations, experiments and problem solving. a. Pascal's Law b. Charles' Law c. Bernoulli's Principle d. Boyle's Law
G. Hydraulic and Pneumatic Educational System Trainers 1. Electromatic Unit 2. Scott Engineering Unit	1. Uses clean compressed air to conduct fluid power experiments. 2. Unit contains a complete hydraulic pressure source and related systems. 3. Safe working practices should be observed and used at all times.	1. Oil content. 2. Chemical reaction to human skin. 3. Chemical reaction on different types of materials (metal, plastic, tubing, etc.).

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Leverage calculation. 2. Multiplication factors of force. Problem solving and experiments. a. 1st class lever b. 2nd class lever c. 3rd class lever d. Wheel and axle e. Screw	1. Investigate current literature containing industrial equipment use and specifications. 2. Develop a plan to organize and codify types of equipment.	
1. Mathematic calculations of area, force, absolute temperature and pressures. Also volume and displacement.		
1. Cost estimation of hydraulic and pneumatic components.	1. Identification of parts and coding systems set up by USASI.	1. Construct a chart illustrating historical development of USASI group of standards from JIC, ASA up to current system being used worldwide.

III. APPLICATION

Show and discuss films: **Compressed Air Power** and **Compressed Air and Gas.** Discuss the history and development of fluid power including hydraulic and pneumatic systems, basic laws and their applications. Introduce both Scott and Electromatic Trainers.

IV. EVALUATION CRITERIA GUIDELINE

A. What is meant by the following terms: Hydraulics, pneumatics, fluid power.

B. List ten applications of fluid power.

C. What is Pascal's Law?

D. What is the ideal gas law?

V. SUMMARY

A fluid power system generates, transmits and controls the application of power through the use of pressurized fluid within an enclosed circuit. A fluid is any material which is capable of flowing: it may be either a gas or liquid. Fluid Power is flexible, efficient, accurate, clean, safe, predictable and readily available.

VI. SUGGESTED TIME and SEQUENCE LISTING

60 minutes . . . Introduce, show and discuss films: **Compressed Air Power** and **Compressed Air and Gas.**

20 minutes . . . History of fluid power . . . lecture.

30 minutes . . . Advantages, applications, hydraulic and pneumatic systems.

30 minutes . . . Science concepts.

30 minutes . . . Math concepts.

160 minutes . . . Electromatic and Scott Educational Trainer Systems.

15 minutes . . . Summary.

15 minutes . . . Evaluation.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

1) **Fluid Power,** NAVPERS 16193, Washington, D. C., U. S. Navy, Superintendent of Documents.

2) **Industrial Hydraulics Manual,** Troy, Mich.: Vickers, Inc., Sperry Rand Corporation, 1968.

3) Stewart, Oscar, **Physics,** New York: Ginn and Company, 1950.

INSTRUCTOR'S UNIT PLAN

Unit 2
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Introduction to Hydraulics**

AIM: Acquaint the student with many industrial hydraulic applications to learn the terms, symbols and schematic diagram language. To familiarize students with a variety of industrial applications of fluid power and to develop an understanding of basic fluid power terminology and schematic symbols.

INSTRUCTIONAL AIDS:

Scott Symbology Schematic Board, Electromatic Hydraulic Trainer or equal, Wall charts and instruction sheets.

Film - **Harnessing Liquids**, Shell Oil Company (12 minutes).

Film - **Basic Hydraulics**, MN-5027A, Navy Training Film available from local lending agency (12 minutes, 16 mm).

EQUIPMENT:

Electromatic Hydraulic Trainer and its accessories and/or Scott Educational Trainer, 16 mm projector and screen.

PRIMARY REFERENCES:

1) **Electromatic Instructor's Manual, Vol. I, Basic Hydraulics**, Box 183 McMinnville, Tenn.: Electromatic Manufacturing Company, Inc., 1963.

2) **Fluid Power Handbook and Directory**, 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

3) Hedges, Charles S., **Industrial Fluid Power, Vol. I**, 2010 Shea Road, Dallas, Texas 75235: Womack Machine Supply Company, 1965-68.

4) **Industrial Hydraulics Manual**, Troy, Mich.: Vickers, Inc., Sperry Rand Corporation, 1968.

I. INTRODUCTION and MOTIVATION

Present film and discuss fluid power applications. Illustrate basic circuits on wall charts and then demonstrate their use.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Hydraulic power 1. Definitions a. Hydraulics b. Power c. Force d. Work e. Pressure f. Velocity g. Flow	1. Definitions. a. Hydraulics is a science based on the physical characteristics of liquids at rest or in motion b. Power is the measure of a given force moving thru a given distance c. Force is defined as any cause which tends to produce or modify motion. It is expressed in units of weight. d. Work is the measure of accomplishment e. Pressure is a force per unit area and is expressed in pounds per square inch (psi)	1. Characteristics of liquids at rest and in motion. a. Mass b. Inertia c. Pressure d. Force 2 Pressure relationship per unit area.
B. Basic hydraulic circuit components	1. A pump is a device which converts mechanical energy into fluid energy. 2. Reservoir is a chamber used to store hydraulic fluid and is usually equipped with breather, strainer and cooling baffles. 3. Fluid is a substance which yields to any pressure tending to alter its shape; fluids include both gases and liquids. 4. Relief valve is a pressure control valve used to limit system pressure. 5. Directional control valve selectively directs or prevents fluid flow through desired channels. 6. Cylinder (actuator) is a linear motion device for converting fluid energy into mechanical energy in which force is proportional to the effective cross sectional area.	1. Fluid composition, shape and state. 2. Fluid flow, friction viscosity, velocity, and pressure.
C. Approved hydraulic and electrical schematic symbols	1. Refer to sketches and charts found in the 1970-71 Fluid Power Directory.	
D. Fundamental electrical component definitions	1. Limit switch is an electromechanical device used to control the action of machines. 2. Electric motor is a device used to convert electrical energy into mechanical energy.	1. Controlling electricity. 2. Electromagnetic induction. 3. Transformers: step-up, step-down.

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Calculations of force, psi and area. 2. Calculation of absolute pressure. (Plus 14.7 psi to gauge pressure).	1. Reading of pressure gauges. 2. Identifying absolute pressure. 3. Measuring with yardstick, scale (weight), and gauges.	1. Early developments and attempts to harness fluid. a. People b. Locations 2. Fluid power technical advancements and its effect upon the working man. a. Economic b. Working conditions
1. Cost per unit item. 2. Comparison of different types of hydraulic circuits per job and performance.	1. Inventory hydraulic components according to manufacturer's specifications. 2. Discussion of the use of symbols in the communication process. 3. Designing a hydraulic circuit using approved symbols.	
1. Calculation of amps, ohms and voltage. 2. Understanding basic electrical units of measurement.	1. Voltage drop or increase read on a meter.	1. Trace historical development of approved schematic symbols. Fluid Power Directory - 1970-71.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
	3. A solenoid is a coil of wire with a moveable iron core. When the coil is subjected to voltage, the core will move. 4. Relay is an electrically controlled device that opens and closes electrical contacts which affects the operation of other devices. 5. Fuse is a metallic device designed to limit maximum circuit load 6. Transformer is a device used to step-up or down voltage.	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES

III. APPLICATION

Introduce the class to basic hydraulic applications. Familiarize students with hydraulic schematics, electrical standards and their necessity to understand hydraulic language.

IV. EVALUATION CRITERIA GUIDELINE

A. Draw the symbols for the following components: variable displacement pump, positive displacement pump, relief valve, reservoir, check valve, pressure control valve and a 4-way, 3-position closed center solenoid actuated valve.

B. List ten industrial hydraulic applications.

V. SUMMARY

Hydraulics is a science based upon the physical characteristics of liquids at rest and in motion. A simple hydraulic circuit consists of a reservoir, pump, relief valve, directional control valve, hoses or lines and an actuator. Hydraulic circuits are illustrated through the use of schematic drawings and component symbols.

VI. SUGGESTED TIME and SEQUENCE LISTING

30 minutes . . . Introduce and show film: **Harnessing Liquids.**

30 minutes . . . Review film and discuss hydraulic applications.

60 minutes . . . Review and discuss the glossary of hydraulic terms, standards and schematic symbols.

120 minutes . . . Familiarize the group with the power unit and worktable of the Electromatic Trainer.

120 minutes . . . Student activity working on hydraulic circuits on the Trainer with instruction sheets.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

1) **Basic Hydraulics TE-6,** Melrose Park, Ill.: International Harvester Company, Construction Equipment Division.

2) **Power Shift Transmission.** Melrose Park, Ill.: International Harvester Company, Construction Equipment Division.

3) Stewart, Oscar, **Physics.** New York: Ginn and Company, 1950.

INSTRUCTOR'S UNIT PLAN

Units . . . . . 3 & 4
Lessons . . . . . 1 & 2
Time . . . . . 12 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Fundamental Physical Laws and Their Application to Fluid Power**

AIM: To develop an understanding of the basic laws of fluids and their use in fluid power.

INSTRUCTIONAL AIDS:

Transparencies - teacher-made; illustrating calculations for determining pressure, force and area.

Film - **Fluid Flow in Hydraulic Systems,** United World Films, Government Films Department, 1445 Park Avenue, New York 29, N. Y. (15 minutes, 16 mm).

Film - **Derivations of Pascal's Law,** Part 1, United World Films, Government Films Department, 1445 Park Avenue, New York, N. Y. (15 minutes 16mm).

Film - **Applications of Pascal's Law,** Part I, United World Films, Government Films Department, 1445 Park Avenue, New York, N. Y. (15 minutes, 16 mm).

Film - **Derivations of Pascal's Law,** Part II, United World Films, Government Films Department, 1445 Park Avenue, New York, N. Y. (15 minutes 16mm).

Film - **Applications of Pascal's Law,** Part II, United World Films, Government Films Department, 1445 Park Avenue, New York (15 minutes, 16 mm).

EQUIPMENT:

Hydraulic Trainer, AC voltmeter & ammeter, 100 lb pull scale, Bernoulli & Torricelli Apparatus, stopwatch, solid cube and a cylinder, 16 mm projector, overhead projector and screen.

PRIMARY REFERENCES:

1) **Electromatic Instructor's Manual, Vol. I, Basic Hydraulics,** Box 183 McMinnville, Tenn.: Electromatic Manufacturing Company, Inc., 1963.

2) **Fluid Power Handbook and Directory,** 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

3) Hedges, Charles S., **Industrial Fluid Power, Vol. I,** 2012 Shea Road, Dallas, Texas 75235: Womack Machine Supply Company, 1965-68.

4) **Industrial Hydraulics Manual,** Troy, Mich.: Vickers, Inc., Sperry Rand Corporation, 1968.

I. INTRODUCTION and MOTIVATION

Explain to students why it is necessary to have an understanding of basic fluid power laws before they can truly understand how and why a circuit operates.

II. PRESENTATION of INTEGRATED CONCEPTS

INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	RELATED CONCEPTS SCIENCE
Lesson 1		
A. Pascal's Law	1. A pressure applied to a confined fluid at rest is transmitted with equal intensity throughout the fluid.	1. Derivations of Pascal's Law. 2. Laminar flow. 3. Turbulent flow. 4. Critical flow.
B. Force formula	1. Force equals pressure (psi) times Area (pir^2) 	
C. Units of measurement	1. Distance equals inches, feet. 2. Area equals sq. in., sq ft. 3. Time equals sec., min. 4. Mass and weight equals lbs., or potential energy (ft./lbs.). 5. Volume equals cu. in., gallons, and cu. ft. 6. Rate equals velocity, speed (ft./sec. or ft./min.). 7. Work equals force through distance (ft./lbs.). 8. Pressure equals lbs. per sq. in. (PSI). 9. Power equals force x distance x time (ft./lbs./sec.). 10. Torque equals ft./lbs. 11. Various expressions of H.P. 12. Heat equals B.T.U.'s.	
D. Fluid power formulas and concepts needed to work hydraulic application problems 1. Laws and concepts a. Boyle's Law (P_1V_1 equals P_2V_2) b. Charles' Law $\left(\frac{V_1}{V_2}\ \frac{T_1}{T_2}\right)$ c. Bernoulli's Theorem. d. Torricelli's Theorem. V equals velocity; ft./sec. (V equals $\sqrt{2gh}$) g equals acceleration of gravity 32 ft./sec.^{2} h equals head - ft.	1. Boyle's Law. a. The absolute pressure of a confined body of gas varies inversely as the volume, provided the temperature remains constant. 2. Charles' Law. a. The volume of fixed mass of gas varies directly with the absolute temperature provided the pressure remains constant.	1. Discussion and explanation of all the laws and concepts underlying Boyle's law and Reynolds Number. 2. Verification and demonstration of above by demonstration and experimentation.

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Math calculations of force, pressure and area. 2. Expression of all the different forms of units of measurement related to hydraulic formula and their applications.	1. Discussion of various levels of communication skills. a. Practical use in automotive industry. b. Everyday use in family living.	1. Biography of Blaise Pascal. 2. Importance of his contributions. 3. Construct a time line illustrating early fluid applications in history.
1. Mathematic calculations of formula. 2. Units for measuring, acceleration force, pressure, and velocity.	1. Comparison of theoretical concepts versus practical application and experimental findings.	1. Biographical sketches of Boyle, Pascal, and Charles and their work which led to their findings. 2. Identify societal needs which their findings satisfied at the time.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
e. D'arcy's Formula $hf = f \times \frac{LU^2}{DZg}$ f. Reynold's Number $R = (.41) \times \frac{(GPM) \times (Sp.Gr.)}{(ID \text{ of pipe sq. in.}) \times (\text{voscosity})}$ g. Pressure drop concept h. Density i. Special gravity $SP = \frac{\text{Weight of substance}}{\text{Weight of an equal volume of water}}$ j. Hydraulic Efficiency $\left(\frac{\text{Efficiency \% equals Output}}{\text{Efficiency \% equals Input}}\right)$ k. Hydraulic Horsepower $HP = \frac{GPM \times PSI \times .000583}{\text{Pump Eff. expressed in dec.}}$ Example: 85% equals .85 l. Mechanical Horsepower. $HP\ Torque \left(\frac{\text{in./lbs.x RPM}}{63025}\right)$ m. Electrical Horsepower. $\left(\frac{\text{Volts x Amps}}{746}\right)$ equals HP	3. Bernolli's Theorem. a. If no work is done on or by a flowing friction less liquid, its energy due to pressure and velocity remains constant at all points along the streamline. 4. Torricelli's Law. a. The liquid velocity at an outlet discharging into the free atmosphere is proportional to the sq. root of the head. 5. Fluid flow through a pipe must encounter frictionless losses. 6. Reynold's Number. a. A Reynold's Number is used to indicate fluid flow through pipes and tubing; classified as laminar, critical and turbulent. 7. Liquid flow through pipe encounters several types of flow resistance, internal pipe friction and resistance due to obstructions in the line. 8. Density. a. Density is expressed as weight per unit volume. 9. SP. a. SP is defined as the ratio of the weight of any volume of a substance to the weight of an equal volume of water. 10. Hydraulic Efficiency. a. Hydraulic efficiency is the comparison between the amount of energy put into a component or system versus the amount of energy put out by the same component or system. 11. Hydraulic Horsepower. a. Hydraulic horsepower is dealt within the form of flow and expressed respectively as GPM and cubic inches per minute. b. Force will be expressed as pounds per sq. in. c. Note: 231 cu. in. equals 1 gal.	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
	12. Mechanical Horsepower. a. Horsepower as applied to rotating shafts uses an expression of torque and RPM's. 13. Electrical Horsepower. a. Power expressed in electrical terms. b. Volts x Amps equals Watts c. 1 HP equals 746 Watts	
Lesson 2 E. Application of formula with practical application 1. Demonstrate laws thru experiments on hydraulic trainer. 2. Perform all calculations and record data. 3. Compare theoretical concepts with specific results of data found thru actual application.	1. Student will prove thru practical application all the technical concepts previously outline in Section (D).	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES

III. APPLICATION

A. Explanation of physical laws of hydraulics with demonstration of each on the electromatic trainer. Chalk board session on formulas and mathematical calculation of data.

B. Class activity to consist of having students prove basic fluid power laws through 'hands on' experimentation.

IV. EVALUATION CRITERIA GUIDELINE

A. State Pascal's Law.

B. How much force is required to lift 50lb weight 2 feet?

C. Calculate pressure and volumes from Boyle's, Charles' and Pascal's Laws using data collected from experiments.

D. Prove Bernoulli's Theorem.

V. SUMMARY

Review the need for understanding the basic fluid power laws and how they are applied in daily activities. Stress the importance of accurate mathematical calculations and its effect upon a safe working circuit.

VI. SUGGESTED TIME and SEQUENCE LISTING

60 minutes . . . Show transparencies. Introduce physical law (theory).

60 minutes . . . Calculation of formulas . . . work out problems.

120 minutes . . . Explanation of hydraulic trainer usage.

60 minutes . . . Reading research material; assigned text readings.

120 minutes . . . Teacher demonstration of physical law application.

300 minutes . . . Student activity working on practical application of physical laws of hydraulics. Prove each one.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

1) Atland, George, **Practical Hydraulics Machine and Tool Blue Book,** Troy, Mich.: Vickers, Inc., Division of Sperry Rand, Inc., 1965.

2) **Operation and Care of Hydraulic Machinery,** New York: Texaco Library and Technical Aids.

3) Stewart, Oscar, **Physics,** New York: Ginn and Company, 1950.

INSTRUCTOR'S UNIT PLAN

Unit 5
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Hydraulic Fluids, Reservoirs, Valves, Tubing and Fittings**

AIM: To develop an understanding of the purpose and function of hydraulic fluids, reservoirs, valves and to plumb a hydraulic circuit.

INSTRUCTIONAL AIDS:

Test tube rack to illustrate the viscosities of oil.

Wall Charts - Electromatic #123 - Electromatic Manufacturing Company, Tennessee, 1965.

Film - **Fluid Flow in Hydraulic Systems,** United World Films, 1445 Park Avenue, New York 29, N. Y. (15 minutes, 16 mm, color).

Film - **Hydraulic Oils,** Texaco District Offices (28 minutes, 16 mm).

Film - **Fluid Flow in Hydraulic Systems,** MN-5027B, Navy training film available from local lending agency (8 minutes, 16 mm).

Transparencies - Series Vol. I, Womack Machine Supply Company, Dallas, Texas.

EQUIPMENT:

16 mm projector, overhead projector, screen, hydraulic circuit and Electromatic Trainer or equivalent.

PRIMARY REFERENCES:

1) **Fluid Power Handbook and Directory,** 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

2) Hedges, Charles S., **Industrial Fluid Power, Volumes I and II,** 2010 Shea Road, Dallas, Texas 75235: Womack Machine Supply Company, 1965-68.

3) **Industrial Hydraulics Manual,** Troy, Mich.: Vickers, Inc., Sperry Rand Corporation, 1968.

I. INTRODUCTION and MOTIVATION

Show film and discuss with the class the purpose and function of various hydraulic circuit components. Make a comparison between the human circulatory system and simple hydraulic circuits.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Hydraulic oil	1. Requirements. a. Conform to the shape of the container b. Oil is relatively incompressible c. Serve as a power transmission agent d. Serve as a lubricating medium and an anti-rust servant e. Serve as a cooling medium or agent 2. Basic types or grades of oil. a. Mineral base oil which is highly refined, with additives meets the required specifications for high HP transmission circuits b. Synthetic chemical additives are introduced to retain fire resistant fluid; yet have lubricating and incompressible characteristics	1. Chemical composition of different grades of oils. 2. Types of chemical additives to retain fire resistant qualities.
B. Characteristics of oils 1. Viscosity 2. Viscosity index 3. SSU (Saybolt Seconds, Universal) 4. Flash point 5. Fire test 6. Pour test 7. Cold test	1. The body of the oil. 2. The index of oil changing its body weight under varing changes of temperature while flowing thru a specific tube for a given amount of time. 3. Term expressed in seconds of time and indicates the time a given amount of oil flows thru a given orifice. 4. Point or temperature standard grade oil will burst into flame. 5. Point at which oil will burn at a sustain flame. 6. Temperature at which oil stops moving or flow. 7. Temperature at which oil (wax) solidifies (solid).	1. Experimental testing of oil and processing each of the basic test of oil (flash, fire, cold and pour).
C. Types of oil flow 1. Laminar 2. Turbulent 3. Critical point	1. Flow that results in a minimum amount of molecular friction due to the velocity of the fluid. 2. Flow that is offering maximum resistance to fluid velocity due to molecular layer friction. 3. Point of flow when laminar flow turns into turbulent flow.	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Calculation of oil flow. 2. Viscosity indexes. 3. Flash point.	1. Classification of viscosity index into chart form. 2. Design a poster showing the processing of crude oil from the ground to the many finished products. (More advanced students may practice developing a transparancy with colored overlays to use as a training or instructional aid.)	1. Different uses of crude oil. a. Origin of crude oil and its many products b. Industrial development of hydraulics into multimillion organizations and companies c. Natural resources of all types are gathered from many countries throughout the world 1) Mining for crude oil 2) Metals 3) Synthetics 4) Chemicals 5) Rubber 6) By-products 7) International effects of import-export relationships of 1) through 6).
1. Experimentation and calculations.		

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
D. Properly constructed and designed reservior	1. General purpose. a. Provide storage space for hydraulic fluid used in circuit b. Prevents contamination of fluid c. Helps maintain proper fluid temperature d. Permits air to escape e. Acts as a base for mounting pump and motor (accessories) f. Acts as a cooler 2. Construction. a. Welded or cast b. Metal thickness (support its load) c. Bottom and sides from 1/8" to 3/16" cold rolled steel 3. Size. a. Design capacity should be approximately three times the pump capacity 4. Component parts. a. Body b. Oil filter c. Air breather d. Drain cock e. Oil strainer f. Pump inlet g. System return line h. Baffleplate	1. Need for atmospheric air pressure to help empty reservoir (air breather). 2. Effects of oil contamination. 3. Foaming action of oil.
E. Types of pipe, hose, and tubing	1. Iron and steel. a. Most economical piping used by industry b. Pipe fitting and threading are all standard c. Do not use galvanized iron pipe (flaking materials into oil stream) d. Available in standard, extra heavy and double extra heavy wall thickness as needed per job pressure requirement e. Steel pipe is classified by schedule numbers (ASA) f. Steel tubing is generally seamless, cold drawn, dead soft annealed g. Steel tubing is designed by its outside wall diameter	1. Copper tubing causes electrolytic action, crystalization and fatigue. 2. Loss of pressure in tubing. a. Friction b. Tube diameter c. Tube length

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Calculation. 2. Cost of components. 3. Sizing of thickness. 4. Reading micrometer and determining diameters.		
1. Calculate prices for tubing fittings, and valves for specific job.		1. Social uses of the various types; relative to in home usage of appliances, etc.

II. PRESENTATION of INTEGRATED CONCEPTS

RELATED CONCEPTS

INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
	2. Copper tubing. a. Should be avoided when selecting tubing because of softness, vibrates, crystalization, electrolytic action and easily fractures 3. Plastic tubing. a. Plastic, nylon and polyvinyl are available for industrial use b. Easily cut to length c. Very flexible d. Not as sturdy as steel e. Vulnerable to hot sparks 4. Rubber synthetic. a. Synthetic rubber not natural rubber is used on industrial circuits b. It is economical, flexible and serves as a shock absorber	
F. Valves (simple valves) and pipe fittings 1. Plug valve 2. Gate valve 3. Globe valve 4. Needle valve 5. Check valve 6. Relief valve	1. Drain cock type goes from open to close with one quarter turn. 2. Consists of a wedge shape gate. When valve is opened a clear fluid flow line is available. 3. Composed of a disc-shaped element which is mounted in its center on the inner end of the valve stem. Flow must change 90° flow thru center of valve. 4. Valve stem end is tapered and fits on a seat when closed. Designed for very precise flow control. 5. Obtainable in various sizes and shapes. Their function is to permit fluid flow in one direction only and block flow in the other. 6. Safety valve used to open when predetermined set pressure has been reached.	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Cost comparison of different types of tubing and fittings.		

III. APPLICATION

Students should fabricate a basic hydraulic circuit using the components covered in this unit. Instruction sheets should be used to insure student safety and to maximize the learning situation.

IV. EVALUATION CRITERIA GUIDELINE

A. What are some important factors to consider in the selection of hydraulic fluids?

B. What is the "rule of thumb" for sizing a hydraulic reservoir?

C. Name three types of tubing used in hydraulic circuit application.

D. Why is pipe or hose sizing very critical?

V. SUMMARY

It is advisable to understand the importance of hydraulic oil characteristics and the components that make up a well-constructed reservoir. The flowing ability of oil thru different conditions of heat, cold, type of tubing, pressure, number of fittings all must be considered when designing a hydraulic circuit.

Review the following:

1. Hydraulic fluids.
2. Reservoirs.
3. Valving.
4. Plumbing.

Emphasize the need for a safety in assembling a hydraulic system.

VI. SUGGESTED TIME and SEQUENCE LISTING

30 minutes . . . Show film and discuss contents.

60 minutes . . . Group will read assigned text.

30 minutes . . . Types,characteristics and flow pattern of oil.

30 minutes . . . Explain reservoir design and construction.

30 minutes . . . Demonstrate types, classification and size.

180 minutes . . . Class activity on instruction sheets (use trainers).

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

1) Ernst, Walter, **Oil Hydraulic Power and Its Industrial Application.** New York: McGraw-Hill Book Company, Inc., 1960.

INSTRUCTOR'S UNIT PLAN

Unit 6
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Hydraulic Pumps**

AIM: To develop an understanding of the principles of pump operation and their application in fluid power.

INSTRUCTIONAL AIDS:

Slides (color) - **Hydraulic Components.** Columbus, Ohio: Denison Engineering Company.

Slides - **Principles of Pump Operation.** Troy, Mich. 48084: Vickers Hydraulics, Sperry Rand Corporation.

Slides - **Hydraulic Pumps.** (36 slides) Volume I, Chapter 5, P. O. Box 35482, Dallas, Texas 75235: Womack Machine Supply Company.

Cutaways of actual gear, vane, piston and combination pumps.

EQUIPMENT:

Slide projector, screen, Electromatic Hydraulic Trainer or equivalent, various hydraulic pumps (with specification manuals).

PRIMARY REFERENCES:

1) **Basic Hydraulics** (NAVPERS 16193), Washington, D. C.: Superintendent of Documents, Government Printing Office, 1962.

2) **Fluid Power Handbook and Directory.** 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

3) **Industrial Hydraulics Manual.** Troy, Mich.: Vickers, Inc., Sperry Rand Corporation, 1970.

I. INTRODUCTION and MOTIVATION

A. Pumps transform mechanical energy into fluid energy and are one of the most widely manufactured components in hydraulics.

B. Slides will be shown illustrating the principles of pumping and the advantages and disadvantages of a variety of hydraulic pumps and pump circuits. Special emphasis will be placed upon selecting the right pump for a particular application.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Gear pump	1. Consists of two rotary gears which revolve and mesh with one another inside a casing. 2. Oil is retained between the gear teeth and the casing. 3. Usually driven by an electric motor, or the power unit of the vehicle which contains the pump. 4. Operate at pressures below 3000 psi. 5. Constant speed and constant fixed displacement delivery pumps. 6. Unbalanced construction-type pump. 7. Shock and contamination resistance is high. 8. Economical.	1. Explanation of change from atomspheric pressure (14.7 psi) to a lower pressure when shaft and gears rotate causing suction on the inlet side of pump.
B. Vane pumps	1. Composed of a shaft, a rotor which contains a number of slots fitted with vanes, an oval-shaped ring, and end plates enclosed in a body. 2. Working pressures are usually below 2000 psi. 3. Can be constant or variable displacement pumps. 4. Constant speed. 5. Usually balanced type pumps. 6. Economical.	1. Heat development in pumping oil at extremely high pressures. 2. Pump cavitation. a. Cause of pump damage b. Lack of lubrication c. Vibration and air into hydraulic pump circuit
C. Piston-type pumps	1. Reciprocating. a. In its simplest form, this pump works on the same principle of lifting water pumps used on forms b. Not to be used at low GPM's c. May be used to develop pressures up to 50,000 psi d. Is a positive displacement pump 2. Radial piston pump. a. A pump having multiple pistons arranged radially and actuated by an eccentric element b. Variable speed and displacement	1. Explanation of how the greater the total resistance to fluid flow in the circuit increases pressure.

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Calculation of GPM. 2. Calculation of hydraulic HP. 3. Calculation of hydraulic pump efficiency. 4. Calculation of piston velocity (ft./min.).	1. Comparison of pump, motor, HP, RPM, weight efficiency and cost of pumps (chart form). 2. Reading of specification bulletins from major hydraulic pump manufacturers. 3. Explanation of pump failures to customers.	1. Historical development of pumps, (from water pumps to high pressure, high efficiency pumps used on armed service ships, planes and vehicles). 2. Military implications of future improvements in pressure and efficiency.
1. Calculation of BTU's. 2. Calculation of calories.	1. Design hydraulic pumping circuits using approved hydraulic schematic symbols.	1. The use of pumps in the medical profession and its impact upon man's well-being. 2. The development of household pumping devices and its effect upon reduction of man's workload. 3. Application of pumping devices to leisure time activities resulting from workload reduction.
1. Calculations of HP, efficiency, torque, leakage, etc.	1. Inventory of available pumps and components. 2. Ordering of pumps and related parts. a. By letter b. Simulated telephone conversation (Bell Telephone supplies free of charge a "Teletrainer" that could be used for developing skills in communication by phone.)	

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
	c. High pressure source d. High efficiency, but expensive to purchase 3. Axial piston pump. a. A pump having multiple pistons arranged with parallel axes b. Swash plate angle is varied to achieve a variable displacement c. High efficiency, but expensive to purchase d. Develops extremely high pressures e. Can be operated at high RPM's	
D. Combination pump (high-low circuit)	1. This type of pump assembly consists of two pumps, one high volume and one of low volume. It utilizes the fundamental hydraulic law that hydraulic HP is a product of both pressure and volume. 2. Used where rapid advance at low pressure with high pressure holding or feed circuit is desired. 3. Achieves substantial savings in HP and generated heat.	1. Volumetric efficiency at high-low pumping circuits.

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Calculations of electrical HP compared to hydraulic HP.		

III. APPLICATION

Display charts, models, cutaways and discuss film (slides). Operate the hydraulic trainer's pump and explain its operation. Assemble and rebuild various types of pumps. Set up basic hydraulic circuits with various pumps.

IV. EVALUATION CRITERIA GUIDELINE

A. Where are combination pumps generally used?

B. What are some definite advantages of piston pumps?

C. Name at least three piston pump designs.

D. How is the volume controlled in radial and axial pumps?

E. What causes the oil to enter the suction side of a gear-type pump?

V. SUMMARY

The construction, design, operational qualities, cost and efficiency vary greatly in hydraulic pumps. Point out the need for correctly selecting the correct pump for a particular job.

VI. SUGGESTED TIME and SEQUENCE LISTING

30 minutes . . . Show slides. Observe cutaways and wall charts. Discuss content and stimulate response.

30 minutes . . . Gear and vane pump explanation, cutaway and operation.

30 minutes . . . Piston type pump explanation, operation and testing.

30 minutes . . . Combination pumps explanation of operation and application.

60 minutes . . . Assembly of pumps. (research specification literature).

180 minutes . . . Student instructional sheets completed on trainer.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

1) Ernst, Walter, **Oil Hydraulic Power and Its Industrial Application.** New York: McGraw-Hill Book Company, Inc., 1960.

INSTRUCTOR'S UNIT PLAN

Unit 7
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Basic Hydraulics . . . Pressure Controls**

AIM: To develop an understanding of the basic principles of hydraulic pressure control valves.

INSTRUCTIONAL AIDS:

Slides - **Pressure Control Valve,** Manchester, Mich.: Double A Products Co.

Slides - **Principles of Valve Operation.** Troy, Mich. 48084: Vickers Hydraulics, Sperry Rand Corporation.

Slides - **Hydraulic Valve Operation.** (36 slides), P. O. Box 35482, Dallas, Texas 75235: Womack Machine Supply Company.

Cutaway of various valves, pressure control valves.

EQUIPMENT:

Slide projector, screen, hydraulic pressure control valves, hydraulic training unit (Vega, Scott or Electromatic).

PRIMARY REFERENCES:

1) **Fluid Power Handbook and Directory,** 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

2) **Industrial Hydraulics Manual.** Troy, Mich.: Vickers, Inc., Sperry Rand Corporation, 1970.

3) **Mobile Hydraulics Manual,** Troy, Mich.: Vickers, Inc., Sperry Rand Corporation, 1967.

I. INTRODUCTION and MOTIVATION

Present slides to students and point out similarities between slide circuitry and hydraulic trainer circuitry. Demonstrate the operation of pressure control valves on the hydraulic trainer.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Pressure theory of fluids	1. Fluid flow without resistance will develop little pressure. 2. As the orifice opening becomes smaller thru which fluid is flowing, the greater the pressure drop and velocity of the oil.	1. Effects of fluid flow and resistance to flow.
B. Relief valves	1. Designed to control and limit maximum hydraulic system pressure. 2. Unbalanced type. Unbalanced . . . commonly called a safety valve. Consist of a spring and a sliding spool; when fluid pressure is greater than spring tension, the valve opens fluid to tank 3. Balanced type. Balanced relief valve (hydrostatically balanced valve) is pilot operated 4. Cracking pressure. This is the pressure required to start flow through a valve. Less than full flow 5. Differential pressure. Pressure required to fully open a valve 6. Pressure overide. The excess pressure which exceeds the adjusted setting due to a valve's inability to respond as quickly as system pressure. Critical in servo systems	1. Physics teacher may help explain cracking pressure, differential and overide characteristics of a relief valve. 2. Spring compression rates.
C. Unloading valve	1. The pump on the hydraulic trainer is equipped with an unloading valve. It is a valve that is used to unload undesired volumes of fluid back to he reservoir.	
D. [illegible]nce valve	1. It is a valve which directs flow to more than one portion of a fluid circuit in correct sequence.	
E. Counterbalance valves	1. Counterbalance, or foot valves, maintain resistance against a flow in one direction but permit free flow in the other.	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Calculations of flow, pressure and resistance thru an orifice.	1. Reading assignments. 2. Instruction sheets organized and properly written.	1. Trace the historical development of pressure control valves and their influence on hydraulic industry's expansion. 2. Map the location of these developments and compare to the locations of major industrial users.
1. Calculation of heat development (BTU's) thru a relief valve.		
1. Calculating psi drops and changes. 2. Calculating needed pressure for specific jobs.	1. Reading of pressure gauges.	
1. Calculating needed HP to move a load in rapid advance. 2. Calculate the HP lost when circuit is in feed cycle.		
1. Calculation or piston speed moving a given load. 2. Calculation of work being preformed.		

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
F. Pressure reducing valve	1. A pressure reducing valve will maintain a reduced pressure at its outlet port regardless of higher inlet pressures.	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES

III. APPLICATION

Disassemble and assemble different types of pressure control valves. Perform basic functions of each pressure control valve in a specific hydraulic circuit. Work out hydraulic calculation on instructional sheets.

IV. EVALUATION CRITERIA GUIDELINE

A. What is the main function of a pressure reducing valve?

B. What is the purpose of sequence valves?

C. What is the purpose of balanced and unbalanced relief valves?

D. Draw the symbol for a relief valve.

V. SUMMARY

Resistance to fluid flow results in the creation of hydraulic pressure. This pressure may be static or dynamic; in applied industrial or mobile applications, it is generally static. To control this energy and regulate its potential pressure, control valves are used in a hydraulic circuit.

VI. SUGGESTED TIME and SEQUENCE LISTING

30 minutes . . . Show slides and discuss various types of pressure valves.

30 minutes . . . Relief Valves . . . balanced and unbalanced.

30 minutes . . . Unloading valves.

60 minutes . . . Pressure reducing valves; sequence valves.

150 minutes . . . Class activity on trainer; assembling circuits with each of the many pressure control valve functions.

60 minutes . . . Work sheets, calculations and circuit design.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

None deemed necessary other than primary.

INSTRUCTOR'S UNIT PLAN

Unit 8
Lesson 1
Time . . . . . 12 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Directional Control Valves**

AIM: To develop an understanding of the purpose and function of directional control valves in a hydraulic circuit.

INSTRUCTIONAL AIDS:

Transparencies - Teacher-made transparencies on valves.

Slides - **Principles of Valve Operation**, Troy, Mich.: Vickers Hydraulics, Sperry Rand Corporation, 1967.

EQUIPMENT:

Overhead projector, screen and cutaways of control valves.

Scott Fluid Power Educational System - Electromatic Educational Program.

PRIMARY REFERENCES:

1) Beiser, Arthur, **Basic Concepts of Physics**, Reading, Mass.: Addison Wesley Publishing Company, Inc., 1961.

2) **Electronic Education Program**, P. O. Box 7398, Nashville, Tenn.: Southeastern Engineering Company.

3) Ernst, Walter, **Oil Hydraulic Power and Its Industrial Application**, New York: McGraw-Hill Book Company, Inc., 1960.

4) Pippinger, J. and Hicks, T. G., **Industrial Hydraulics**, New York: McGraw-Hill Book Company, Inc., 1962.

I. INTRODUCTION and MOTIVATION

Through the use of cutaways and wall charts, explain to the students the need to control the directional flow of fluid in order to perform useful work.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Check valves	1. Types a. Inline b. Angle check c. Adjustable d. Pilot operated 2. Application. a. Multiple-pump installations b. Inlet side to hod prime c. Used with flow control valves d. Sequence and check e. Back pressure f. Deceleration valves g. Heat exchanger application	1. Pressure drops. 2. Spring compression and heat engines. 3. Heat transfer and heat engines.
B. Rotary pilot valve.	1. Function. a. Low pressure operation b. Operate main control valve 2. Operation. a. Held in position by detents b. Operated manually, electronically, or hydraulically 3. Classified as follows. a. Type of mount b. Type of body c. Type of lever d. Type of center 4. Piping. a. ¼" pipe size b. ⅜" steel tubing 5. Capacity. a. Rotary - 3 GPM - maximum pressure 2,000 psi b. Sliding spool - 3 GPM - maximum pressure 2,000 psi	
C. Directional control valves	1. Number of directions. a. One way b. Two way c. Three way d. Four way e. Others 2. Type of spools. a. Poppet b. Sliding c. Rotary 3. Method of operation. a. Manually b. Mechanically c. Pilot d. Electrically	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Fractions and decimals used in determining the size of tubing and pipe fittings.	1. Reading of the U.S.A.S.I. symbols on the symbology chart.	1. Studying the history and development of the United States of America Standards Institute. 2. Compare advantages and disadvantages of governmental vs. industrial initiation and supervision of standards.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
	4. Spool modifications a. Open center b. Closed center c. Spool position arrangement 1) Spring centered 2) Spring offset 3) No springs	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES

III. APPLICATION

Show slides and discuss directional control valves with students. Set up hydraulic circuits on the trainer, incorporating various types of directional control valves and have students complete instruction sheets.

IV. EVALUATION CRITERIA GUIDELINE

A. Check valves permit flow of oil in only one direction. T F

B. Directional control valves are operated (a) electrically, (b) mechanically, (c) hydraulically, (d) manually, (e) all of the above.

C. Two designs of directional valves are rotary and spool type? T F

V. SUMMARY

In order to perform any useful work hydraulically, it is necessary to control the direction of the hydraulic oil. This is done very simply with the use of a directional control valve. The type of directional control valve will be determined by the design of the circuit.

VI. SUGGESTED TIME and SEQUENCE LISTING

60 minutes . . . Theory - Check valves.

60 minutes . . . Theory - Rotary pilot valves.

60 minutes . . . Theory - Directional control valve.

60 minutes . . . Practical experiences.

60 minutes . . . Practical experiences.

60 minutes . . . Prac'ical experiences.

260 minutes . . . Theory and practical experiences with check, rotary, and directional control valves.

100 minutes . . . Related instruction in science, math, communications and social studies.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

1) **Fluid Power,** NAVPERS 16193, Washington, D. C.: U. S. Navy, Superintendent of Documents.

2) **Fluid Power Handbook and Directory,** 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

3) Hedges, Charles S., **Industrial Fluid Power, Vols. I and II,** 2010 Shea Road, Dallas, Texas 75235: Womack Machine Supply Company, 1965-68.

4) **Industrial Hydraulics Manual,** Troy, Mich.: Vickers, Inc., Sperry Rand Corporation, 1968.

INSTRUCTOR'S UNIT PLAN

Unit 9
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Linear Actuators and Accumulators**

AIM: To develop an understanding of the purposes and operation of linear actuators and accumulators.

INSTRUCTIONAL AIDS:

Slides - **Principles of Hydraulic Actuators**, Troy, Mich. 48084: Vickers Hydraulics, Sperry Rand Corporation.

Slides - **Accumulators**, P. O. Box 35482, Dallas, Texas 75235: Womack Machine Supply Company (36 slides).

EQUIPMENT:

Scott Engineering Education System, hydraulic cylinders, accumulators, Vega hydraulic trainer, slide projector and screen.

PRIMARY REFERENCES:

1) **Basic Hydraulics**, NAVPERS 16193, Washington, D. C.: Bureau of Navy Personnel.

2) **Fluid Power Handbook and Directory**, 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

3) Hedges, Charles S., **Industrial Fluid Power**, 2010 Shea Road, Dallas, Texas 75235: Womack Machine Supply Company, 1965-68.

4) **Hydraulic Power Laboratory Manual**, Decatur, Ill.: Vega Enterprises, 1966.

I. INTRODUCTION and MOTIVATION

Show slides and discuss the principles of operation and uses of linear actuators and accumulators. Demonstrate their purposes on the hydraulic trainers.

II. PRESENTATION of INTEGRATED CONCEPTS

RELATED CONCEPTS

INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Hydraulic cylinders	1. Single acting. a. Apply a force in one direction 2. Double acting. a. Apply a force in two directions b. Reciprocating 3. Telescoping type. a. Extended strokes 4. Double rod ends. a. Equal speed in each direction b. Capable of doing work at both ends	1. Review Pascal's Law. 2. Review force, pressure, area. 3. Rate of cylinder extension and retraction. 4. Archimedes' principle and buoyant forces.
B. Valving	1. Flow control valves. a. Variable b. Allows free flow in one direction c. Controls speed of cylinder movement 2. Directional control valve. a. Four-way valve 1) Spool type 2) Operated either manually, electrically, mechanically, or hydraulically b. Check valve 1) Allows free flow in one direction 2) Incorporated into the flow control valve	
C. Accumulators	1. Store potential energy. a. Sometimes used as a safety valve b. Delivers pressure when needed 2. Types. a. Weight loaded b. Spring loaded c. Pneumatic loaded (pressure)	1. Potential energy versus kinetic energy.

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Determining the area of a circle. 2. Determining the volume of a cylinder. 3. Calculate multiplication of force using Pascal's Law. 4. Calculate specific gravity and density.	1. Collecting and recording data on student worksheets.	1. Study the origin, development and growth of hydraulic cylinders and their application. 2. The effect of cylinders in reducing man's workload. 3. The economic effects of man's reduced workload. 4. The importance of cylinders relative to increased production of consumer goods.

III. APPLICATION

Discuss the various types of cylinders and accumulators and their importance to hydraulic circuits. Explain the circuitry uses in conjunction with cylinders. Have students set up operations and complete student worksheets.

IV. EVALUATION CRITERIA GUIDELINE

A. What type of cylinder exerts a force in one direction?
Single Action Cylinder

B. What type of cylinder exerts a force in two directions?
Double Acting Cylinder

C. What device is used to store potential energy?
Accumulator

V. SUMMARY

A. Single acting cylinders apply a force in one direction and must be returned by a force other than hydraulic. Double acting cylinders are used to apply a force in two opposite directions, and will be capable of reciprocating movement.

B. Accumulators are used to store potential energy in an incompressible fluid for subsequent conversion into useful work.

VI. SUGGESTED TIME and SEQUENCE LISTING

80 minutes . . . Cylinders and application theory.

120 minutes . . . Practical.

60 minutes . . . Accumulators and application theory.

80 minutes . . . Practical

20 minutes . . . Evaluation.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

1) Stewart, Oscar, **Physics**, New York: Ginn and Company, 1950.

INSTRUCTOR'S UNIT PLAN

Unit 10
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Flow Control Valves**

AIM: To develop an understanding of the purpose and operation of hydraulic flow control valves and their specific application in basic hydraulic circuits.

INSTRUCTIONAL AIDS:

Slides - **Hydraulic Flow Control Valve Operation.** Troy, Mich. 48084: Vickers Hydraulics, Sperry Rand Corporation, 1867.

Slndes - **Flow Control Valves.** P. O. Box 35482, Dallas, Texas 75235: Womack Machine Supply Company.

Wall Chart - **Flow Control Valves.** Double A Valve Company.

EQUIPMENT:

Scott Engineering Educational System, Electromatic Hydraulic Trainer and Vega Hydraulic Trainer, slide projector and screen.

PRIMARY REFERENCES:

1) **Electromatic Instructor's Manual, Vol. I, Basic Hydraulics.** Box 183, McMinnville, Tenn.: Electromatic Manufacturing Company, Inc., 1963.

2) **Fluid Power,** NAVPERS 16193-A, Washington, D. C.: U. S. Navy, Superintendent of Documents.

3) **Fluid Power Handbook and Directory.** 812 Huron Road Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

4) Hedges, Charles S., **Industrial Fluid Power.** 2010 Shea Road, Dallas, Texas 75235: Womack Machine Supply Company, 1965-68.

I. INTRODUCTION and MOTIVATION

Show slides and discuss with students the use of flow control valves in a hydraulic circuit. Demonstrate valves of hydraulic trainer.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Plug valves	1. Sometimes referred to as a cock. 2. Used for either fully on or fully off. 3. Not used to vary the volume of flow. 4. Sometimes used as a bleed valve. 5. Construction of a. Hollow cylindrical body b. Tapered plug	
B. Gate valves	1. Controls flow by means of a wedge or gate. 2. Controlled by a handwheel. 3. Permit straight flow. 4. Used for either fully open or fully closed. 5. Not used to vary the volume of flow.	
C. Globe valves	1. Derive name from body shape. 2. Controls flow by means of a disc which is screwed down into the seat. 3. Controlled by a handwheel. 4. Usually used in the fully opened or fully closed position. 5. Sometimes used to vary the volume.	
D. Needle valves	1. Similar in design and operation to globe valves. 2. Controls flow by means of a needle which is screwed down into a seat. 3. Long taper permits the valve to be open or closed gradually. 4. Used to vary volume of flow.	1. Bernoulli's Theorem.

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Computing pressure drops across valves.	1. The study of and the practice of using the U.S.A.S.I. graphic symbols.	1. The development of flow control valves and its effect upon the hydraulic industry. 2. The significance of flow control valves to states and regions.

III. APPLICATION

Discuss the various types of flow control valves, set up and demonstrate a hydraulic circuit using flow control valves; have students complete student worksheets.

IV. EVALUATION CRITERIA GUIDELINE

A. What is a flow control valve?

B. Name three different types of flow control valves.

C. What is a gate valve?

D. What is a needle valve?

V. SUMMARY

A flow control valve is a hydraulic valve that controls the flow of fluid. The flow control may be either on or off, or variable. A plug valve controls the flow, but not volume. The gate valve also is of the on and off variety. The globe valve and needle valve are used to control the volume as well as opening and closing flow.

VI. SUGGESTED TIME and SEQUENCE LISTING

30 minutes . . . Introduction.

30 minutes . . . Plug valve theory.

30 minutes . . . Gate valve theory.

30 minutes . . . Globe valve theory.

30 minutes . . . Needle valve theory.

150 minutes . . . Integrated curriculum concepts.

30 minutes . . . Summary.

30 minutes . . . Evaluation.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

None deemed necessary other than primary.

INSTRUCTOR'S UNIT PLAN

Unit 11
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Fluid Motors and Related Components**

AIM: To develop an understanding of the principles of hydraulic motors, intensifiers and surge valves and their applications in hydraulic circuitry.

INSTRUCTIONAL AIDS:

Slides - **Rotary Actuators.** Troy, Mich. 48084: Vickers Hydraulics, Sperry Rand Corporation.

Slides - **Hydraulic Motors and Intensifiers.** P. O. Box 35482, Dallas, Texas 75235: Womack Machine Supply Company.

Teacher-made transparencies and motor cutaway.

EQUIPMENT:

Scott Engineering Company Educational System and Electromatic Hydraulic Trainer, slide projector and screen.

PRIMARY REFERENCES:

1) **Electromatic Instructor's Manual, Vol. I, Basic Hydraulics.** Box 183, McMinnville, Tenn.: Electromatic Manufacturing Company, Inc., 1963.

2) **Fluid Power,** NAVPERS 16193-A, Washington, D. C.: U. S. Navy, Superintendent of Documents.

3) **Fluid Power Handbook and Directory,** 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

4) Hedges, Charles S., **Industrial Fluid Power,** 2010 Shea Road, Dallas Texas 75235: Womack Machine Supply Company, 1965-68.

I. INTRODUCTION and MOTIVATION

Illustrate the principles of operation and function of hydraulic motors, intensifiers and surge valves through the use of slides and transparencies. Discuss their specific application in a hydraulic circuit with the students.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Fluid motors. 1. Operating principles 2. Types	1. A fluid motor is an actuating unit used when rotary motion is desired. 2. Rotary fluid motor. a. Vane type b. Gear type c. Piston type 3. Fixed and variable displacement. 4. Oscillating motor. Paddle motor (windshield wipers)	1. Hydrodynamic principles. 2. Hydrostatic principles.
B. Intensifiers. 1. Definition 2. Types 3. Advantages	1. An intensifier is a device which multiplies pressure. 2. Oil to oil. 3. Air to oil. 4. Oil - mechanical. 5. High pressure can be maintained for long periods of time without overburdening the pump. 6. No heat problem. 7. No large reservoirs required. 8. Can be used with ordinary shop air when no fluid power is available.	1. Relative incompressibility of fluids. 2. Review Pascal's Law. 3. Transmission of pressure.
C. Surge valve. 1. Operating principles 2. Types	1. The surge valve is normally closed and opens only when pressure is applied to the inlet side. This valve allows for a gradually accelerated flow through the valve until fully open. After the period of acceleration, virtual flow is maintained as long as fluid continues to flow through the valve. When flow is interrupted, the valve resets. 2. Reciprocating cycle control panel. a. Application 1) Moving a slide or table back and forth in a controlled reciprocating motion b. Controls 1) Manual 2) Mechanical c. Other units 1) Pilot choke 2) Auxiliary pilot connection	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. The formula for finding the area of a circle: A equal pi R^2 2. The formula for finding force: F equal AxP 3. F equal $\frac{a}{A}$w hydraulic press law	1. A review of the U.S.A.S.I. graphic symbols.	1. The history and development of fluid motors, intensifiers and surge valves. 2. Use potential for emerging underdeveloped nations; e.g., construction of dams to harness power.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
	3. Traverse and feed cycle control panel. a. Application 1) Controlling the direction and speed of the worktable and slide b. Controls 1) Manual 2) Mechanical 3) Electrical	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES

III. APPLICATION

Discuss the use of fluid motors, intensifiers and surge valves with the students. Set up and demonstrate various circuits using these components and have students complete student worksheet.

IV. EVALUATION CRITERIA GUIDELINE

A. What is a fluid motor?

B. What is a hydraulic intensifier?

C. What is a surge valve?

D. Sketch a hydraulic intensifier circuit.

V. SUMMARY

Fluid motors are used when rotary motion is desired. These units are used in such applications as: lifts, hoists and pulleys. An intensifier is a device which multiplies pressure. It is used in circuits where high pressure is needed and a high pressure pump is not available. Surge valves are used when reciprocating movement is desired.

VI. SUGGESTED TIME and SEQUENCE LISTING

55 minutes . . . Introduction.

30 minutes . . . Fluid motor theory.

60 minutes . . . Intensifiers theory.

45 minutes . . . Surge valves theory.

120 minutes . . . Integrated curriculum concepts.

25 minutes . . . Summary.

25 minutes . . . Evaluation.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

None deemed necessary other than primary.

INSTRUCTOR'S UNIT PLAN

Unit 12
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Mobile and Industrial Hydraulic Circuitry**

AIM: To develop an understanding of basic hydraulic circuitry as applied to mobile and industrial systems.

INSTRUCTIONAL AIDS:

Slides - **Mobile Circuits and Circuit Diagrams,** Troy, Mich.: Vickers Hydraulics, Sperry Rand Corporation, 1967.

Film - **Hydraulic Turret Traversing Mechanism.** 1560 W. Pierce Street, Milwaukee 4, Wisconsin: The Oilgear Company (22 minutes, 16 mm, sound).

Transparencies - teacher-made; illustrating basic industrial and mobile circuits.

EQUIPMENT:

Scott Engineering Educational System, Electromatic Hydraulic Trainer, 16 mm projector, overhead projector and screen.

PRIMARY REFERENCES:

1) **Electromatic Instructor's Manual.** McMinnville, Tenn.: Electromatic Manufacturing Company, Inc., 1963.

2) **Fluid Power Handbook and Directory.** 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

3) Hedges, Charles S., **Industrial Fluid Power,** 2010 Shea Road, Dallas, Texas 75235: Womack Machine Supply Company, 1965-68.

4) **Mobile Hydraulics Manual.** Troy, Mich.: Vickers, Inc., Sperry Rand Corporation, 1967.

I. INTRODUCTION and MOTIVATION

Illustrate and discuss basic industrial and mobile hydraulic circuits. Place special emphasis on the similarities and differences between each type of circuit and its application.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Mobile circuits 1. Common applications	1. Power steering. a. Automobiles b. Trucks	1. Review Pascal's, Charles, and Boyle's Laws.
	2. Power tailgate.	
	3. Fork-lift trucks.	
	4. Tractors. a. Back hoe b. Front-end loaders	
	5. Earthmoving equipment.	
	6. Gun turrets.	
2. Characteristics	7. Manually operated. a. Require skilled operator b. Usually operated by levers	
	8. Intermittent duty cycle. a. Used only for short periods of time	
	9. High RPM pump driver. a. Pumps are driven by vehicle engine b. RPM range from 400 to 6,000; pump must operate at all speeds	
3. Single acting cylinders	10. Extend by pressure, returned by load. a. Usually equipment has enough weight to return cylinder	2. The study of Pascal's Law.
4. Power steering	11. Advantages. a. Less lines needed b. Less valving is required c. Less expensive	
	12. Ideal system. a. Sensitive response b. Adequate roadful c. Sufficient power d. Uniform response regardless of engine RPM	
5. Multiple spool valves	13. Tandem circuits.	
	14. Open center. a. Allows for oil return to the reservoir when in neutral position	
	15. Closed center. a. Does not allow for oil return in the neutral position	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Formula for Pascal's Law. F equals AP 2. Formula for HP and its derivatives. HP equals Torque $\times$ RPM / 63000 3. The study of ratios. 4. Definitions, experiments and calculations. a. Force b. Work c. Power d. Horsepower	1. Giving directions to hydraulic equipment operators.	1. The history and development of labor unions for operators of hydraulic machinery. 2. Identify various environments which may be conducive to different hydraulic applications. 3. Importance of hydraulic machinery to man in changing his environment to meet his needs.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
B. Industrial circuits 1. Common applications 2. Basic components. 3. Physical laws relating to HP and torque.	1. Production tooling. 2. Synchronizing circuits. 3. Speed control circuits. 4. Machine tool circuits. 5. Fluid motor circuits. 6. Reservoir. 7. Pump. 8. Directional control. 9. Actuator. 10. Horsepower. a. Torque b. RPM c. HP equals $\frac{\text{Torque x RPM}}{63000}$ 11. Gear ratios.	1. The development of horsepower calculating.

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES

III. APPLICATION

Students should set up a variety of hydraulic circuits with the aid of teacher-prepared instruction sheets.

IV. EVALUATION CRITERIA GUIDELINE

A. List three common uses of hydraulic mobile circuits.

B. List three characteristics of hydraulic mobile circuits.

C. What is the ideal power steering system?

D. Name two applications of industrial circuits.

E. List the basic components of any hydraulic circuits.

V. SUMMARY

Hydraulic circuitry is used in many applications. It is estimated that approximately 50% of all industrial components produced utilize some form of fluid power. Mobile hydraulics are found in many automotive power steering systems and in such dynamic applications as shovel circuits on gigantic earth-moving equipment.

VI. SUGGESTED TIME and SEQUENCE LISTING

30 minutes . . . Introduction.

60 minutes . . . Mobile circuitry theory.

90 minutes . . . Practical.

60 minutes . . . Industrial circuit theory.

90 minutes . . . Practical.

30 minutes . . . Summary and evaluation.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

1) Barnard, J. Darrell, **Science: A Key to the Future**, New York: The Macmillan Company, Publishers, 1962.

INSTRUCTOR'S UNIT PLAN

Unit 13
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Introduction to Pneumatics**

AIM: To develop an understanding of various components, instrumentation, piping and mountings used in typical pneumatic circuits.

INSTRUCTIONAL AIDS:

Filmstrip and Record - **Elements of Compressed Air.** Cleveland, Ohio: Parker-Hannifin Corporation.

Wall Chart - **Compressed Air Power.** Cleveland, Ohio 44113: Compressed Air and Gas Institute, Room 1200-55 Public Square.

Film - **Compressed Air and Gas.** Cleveland, Ohio 44113: Compressed Air and Gas Institute, Room 1200-55 Public Square (26 minutes, 16 mm).

EQUIPMENT:

Electromatic Pneumatic Trainer and related components, 16 mm projector, filmstrip projector, screen and record player.

PRIMARY REFERENCES:

1) **Compressed Air and Gas Handbook.** New York: Compressed Air and Gas Institute, 1970.

2) **Electromatic Manual for Pneumatics,** McMinnville, Tenn.: Electromatic Manufacturing Company, Inc., 1963.

3) **Fluid Power Handbook and Directory.** 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

I. INTRODUCTION and MOTIVATION

Show film and discuss with students the applications of pneumatics. Display wall chart and introduce students to the pneumatics trainer.

II. PRESENTATION of INTEGRATED CONCEPTS

RELATED CONCEPTS

INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. General construction.	1. Gives maximum flexibility in mounting, connecting, demonstrating or experimenting with any or all equipment furnished.	1. Lubricator functions on the same principle as the venturi tube operates.
	2. Mounting trays are strong, flexible and easily applicable when mounting components.	
	3. Bulkhead quick disconnect fittings, plastic tubing and small plastic ferrule which can be all hand-tightened.	
1. Air supply	4. Need compressor with 150 psi maximum and a pressure relief valve set at 90 psi.	
2. Filter	5. Removes impurties which were not trapped by the receiver.	
3. Regulator	6. Instrument used to reduce pressure below main line pressure (relieving type).	
4. Lubricator	7. Calibrated instrument which meters a certain amount of oil into the air stream to oil and lubricate components and equipment as needed.	
B. Electrical.	1. Power for the electrical panel is furnished by a step-down transformer.	1. Physics demonstration of transformer and all electrical accessories used on trainer.
	2. Voltage supplied to the panel is 24 VAC.	
	3. Input to transformer is 115 VAC.	
	4. Panels may be completely disconnected from the power supply.	
	5. Panels contain switches, relays, contacts, timer and wired pin jacks. All needed to perform various electrical circuits.	
C. Instrumentation. 1. Manometer	1. Instrument used to measure pressure or differential pressure. a. U-tube type b. Filled with mercury or water c. Scales are graduated in inches of H_2O equals .036 psi	1. The relationship between inches of mercury and pressure gauge readings.

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Mathematical calculations for lubricator setting. (Drops of oil to number of RPM's).	1. Inventory of all components. 2. Reading specification bulletins from various manufacturers who supply components and accessories.	1. The history of pneumatic tools in relation to the industrial revolution. 2) Orgin, development and importance of industrial safety programs.
1. Converting 115 VAC to 24 VAC (transformer action). 2. Convert water readings on the manometer to psi of pressure drop.	1. Reading a voltmeter. 2. Reading a manometer. 3. Reading a rotometer.	1. The rise of the mass production system and its effects upon: a. The labor market b. Standard of living c. Consumer economics d. Advertising industry
1. Calculation of SCFH to SCFM.		

II. PRESENTATION of INTEGRATED CONCEPTS

RELATED CONCEPTS

INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
2. Rotometer	2. Is used to measure the flow of fluids, either liquids or gases. 3. Flow through the tube increases, the orifice area increases between the sphere and inside of the glass tube.	2. Laboratory experiment on the principles of operation of the rotometer.
3. Pressure gauges.	4. Each position of the float is for a specific flow which is proportional to the orifice area. a. Readings are taken in the center of the sphere b. Scale is graduated in SCFH	3. Gauge pressure minus 14.7 (atmospheric pressure) equals Absolute Pressure.
4. Timer.	5. Instrument which measures static air pressure. a. Graduated from 0-60 psi and 0-30 and 0-100 psi b. Sudden pressure surge may damage gauges 6. Calibrated in 1/5 of a second. 7. Wired for both parallel and series hookups. 8. Has a reset lever.	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
2. Calculation of absolute pressure.	1. Reading a timer. 2. Charting a timer sequencing in various pneumatic circuits.	

III. APPLICATION

Students should be required to complete a series of assignment sheets which are designed to familiarize them with the operation of the pneumatic trainer.

IV. EVALUATION CRITERIA GUIDELINE

A. The rotometer is used for what purpose?

B. What is the maximum temperature that can be withstood by polyethylene tubing?

C. What is the function of U-tube manometers?

D. Why is "horseplay" dangerous?

V. SUMMARY

Review and summarize the application of pneumatics in contemporary society. Also review the operation of the pneumatics trainer.

VI. SUGGESTED TIME and SEQUENCE LISTING

60 minutes . . . Film or filmstrip and charts. Discussion of pneumatics.

60 minutes . . . Construction of the trainer, mounting, piping and air systems.

60 minutes . . . Electrical operation of trainer.

60 minutes . . . Instrumentation - principles of operation and its purpose.

120 minutes . . . Instructor demonstration followed by student class activity.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

None deemed necessary other than primary.

INSTRUCTOR'S UNIT PLAN

Unit 14
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Applied Physics as Related to Pneumatics**

AIM: To develop an understanding of the laws of mechanics, gas and fluids as applied to the field of pneumatics.

INSTRUCTIONAL AIDS:

Slides - **Industrial Fluid Power Vol. II**, Dallas, Texas: Womack Machine Supply Company, 1968 (35 mm).

EQUIPMENT:

35 mm slide projector, screen, weights, scale, thermometer and Electromatic Pneumatic Trainer.

PRIMARY REFERENCES:

1) Eshbach, O. W., **Handbook of Engineering Fundamentals**, New York: John Wiley and Sons, Inc., 1952, Second Edition.

2) Glasstone, Samuel and Lewis, David, **Elements of Physical Chemistry**, Princeton, N. J.: D. Van Nostrand Company, Inc., 1960, Second Edition.

3) Hedges, Charles S., **Industrial Fluid Power, Vol. II**, 2010 Shea Road, Dallas, Texas 75235: Womack Machine Supply Company, 1965-68.

4) Poorman, Alfred P., **Applied Mechanics**, New York: McGraw-Hill Book Company, Inc., 1965, Fifth Edition.

I. INTRODUCTION and MOTIVATION

View slide series and discuss the importance of understanding the basic laws of mechanics, gas and fluids as applied to pneumatics.

II. PRESENTATION of INTEGRATED CONCEPTS

RELATED CONCEPTS

INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Mechanics in general. 1. Basic definitions a. Statics b. Dynamics c. Translatory motion d. Rotary motion e. Kinematics	1. The study of forces applied to any physical body at rest and the forces applied to any physical body in motion with respect to time. a. Statics is a study of applied mechanics which considers only bodies in equilibrium with respect to time b. Dynamics is that part of applied mechanics which considers only bodies in motion c. Translatory motion is motion of a body in a straight line d. Rotary motion is the movement of a body in a circle around a fixed center point e. Kinematics is that part of dynamics which considers the motion of bodies without reference to the forces causing the motion	1. All technical concepts may be demonstrated with physics lab equipment for greater clarification and explanation. 2. Student experiments. a. Falling bodies b. Weighted carts
B. Average velocity of a piston rod.	1. Calculations from average velocity formula: V equals $\frac{s}{t}$ a. s equals distance, miles, feet, inches b. t equals time, hours, minutes, seconds c. V equals velocity or speed, ft./min., miles/hr.	
C. Acceleration. 1. Units of time 2. Acceleration formula	1. Acceleration is the rate of change of velocity per unit of time. a. ft./sec.², in./sec.², etc. b. V_f equals V_o plus at a equals average acceleration Vf equals final velocity Vo equals initial velocity	
D. Kinetics. 1. Newton's three laws of motion	1. Law I . . . A body at rest or in uniform straight line motion remains at rest or remains in straight motion unless acted upon by some external force. 2. Law II . . . A body acted upon by a resultant force receives an acceleration in the direction of the force which is proportional to the force and inversely proportional to the mass of the body.	1. Physics lab experiments of Newton's three laws. a. Develop definitions 1) Force 2) Acceleration 3) Inertia 4) Mass 5) Velocity b. Units of measurement 1) Newton's 2) Dynes

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Mathematical calculations of formula data.		1. Construct a time line depicting man's efforts to overcome friction in moving objects; from the earliest known civilizations to the present day.
	1. Develop a graph or chart which correlates distance and time in relationship to the velocity of various types of air cylinders.	
1. Mathematical calculation of acceleration.	1. Develop graphs and charts showing speed and rate of increases between velocity and distance.	
		1. Biography of Sir Isaac Newton.

II. PRESENTATION of INTEGRATED CONCEPTS

RELATED CONCEPTS

INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
2. Net resultant force required to uniformly accelerate a body into motion	3. Law III . . . For every action, there is an equal and opposite reaction of the body. 4. Formula F equals Ma. a. F equals net force on the body (lbs.) b. M equals mass of the body (w/g) c. a equals acceleration of body (ft./sec²)	3) Grams 4) Slugs
E. Friction. 1. Coefficient of static friction	1. Static, kinetic and rotary are different forms of friction. 2. The ratio of force required to start motion to force pressing on the surface that is perpendicular to the sliding plane. 3. Kinetic friction . . . force to keep body moving. 4. Rolling friction of any body and its resistance to roll.	1. Lab experiments which will express static, kinetic and rotary concepts. a. Calculation of rolling and sliding bodies. b. Experiments with frictionless pucks.
2. Formula for static friction, kinetic friction and rolling friction	5. fk equals $\frac{F_k}{F_n}$ 6. fs equals $\frac{F_s}{F_n}$ 7. F equals $\frac{W_b}{r}$	
F. Springs. 1. Spring constant. 2. Formula for spring constant	1. Compression and extension springs used in pneumatic circuits. 2. The pounds required to move a spring one inch. 3. V equals Ks	1. Lab experiments which will express spring constant use in pneumatic circuits. 2. Lab experiments with various types of thermostats.
G. Gas Laws. 1. Temperature	1. Centigrade. °C equals 5/9 (F-32) 2. Rankine (absolute) F°. plus 460 with F° reading 3. Kelvin (absolute) C°. plus 372 with C° reading	
2. Measurement	4. Thermocouple. Two dissimilar metals when fused together will generate a small voltage if subject to heat 5. Bimetallic. Two dissimilar metals bonded together will expand differently when heated	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Calculation of resultant forces and review vectors.		
1. Calculate mathematical friction formulas.	1. Graphs and charts.	
1. Calculation of centigrade and absolute temperature. 2. Conversions from one temperature measurement system to another.	1. Reading thermometer. 2. Reading Rankine and Kelvin scales.	

II PRESENTATION of INTEGRATED CONCEPTS

RELATED CONCEPTS

INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
3. Charles' Law	6. Expanding fluids Any liquid will expand when heated	1. Lab experiments of Charles' Law and Boyle's Laws.
	7. Formula. a. If the pressure of a gas remains constant the volume will be directly proportional to the temperature b. V_1 equals T_1 / V_1 equals T_2	2. Lab experiments varying both pressure and temperature. $\frac{P_1V_1}{T_1}$ equal $\frac{P_2V_2}{T_2}$
4. Pressure and Boyle's Law	8. Boyle's Law. If the temperature of a gas is held constant the volume will be inversely proportional to the pressure	
	9. Formula.	
	10. Absolute pressure.	
H. Fluid flow. 1. Standard conditions of a gas	1. Refers to an established base temperature and pressure when specifying the volume.	1. Lab experiments varying temperature, pressure, and volume.
	2. At base conditions, the volume of one mole of any gas is equal to a constant.	
2. Flow formulas	3. Thru a pipe . . . flow and pressure are related to the fanning friction factor.	
	4. Thru restrictions where down stream pressure is greater than 50% of upstream pressure. The flow is proportional to the sq. root of the pressure drop across the restriction.	
	5. Thru a restriction where downstream pressure is less than 50% of the upstream pressure. The flow is directly proportional to the upstream pressure.	
3. Specific gravity of a gas	6. Is equal to the density of the gas divided by the density of air at the same conditions of pressure and temperature. Air equals 1.0 specific gravity	
4. Flow rate (SCFH)	7. Q_1 euaqls Q_2 $\frac{P_1T_2}{P_2T_1}$	
5. Flow coefficient of a gas thru a valve	8. C_V equals $\frac{Q\sqrt{GT}}{1360\sqrt{P_2(\triangle P)}}$	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
3. Mathematical calculations of Boyle's and Charles' Laws on gases.		1. Biographical sketch of Charles' and Boyle's scientific lives and works.
4. Flow rate calculations. 5. Flow coefficient calculations.	1. Flow rate charts. 2. Flow coefficient graphs. 3. Reading rotameters and manometers.	

III. APPLICATION

The use of instruction sheets to apply the basic laws of physics on the pneumatic trainer with calculations and proof of all laws applying to pneumatics.

IV. EVALUATION CRITERIA GUIDELINE

A. If an object travels 100 yards in 30 seconds, what is its average velocity in feet per minute?

B. Explain kinematics as applied to pneumatics.

C. When a gas is heated from 60 F to 100 F, what is the volume change in a 10 cubic inch cylinder?

D. What is an orifice plate and how is it applied?

V. SUMMARY

The basic laws of mechanics, gases and fluids must be understood in order to increase the student's background and foundation for future work in pneumatic controls and application.

VI. SUGGESTED TIME and SEQUENCE LISTING

30 minutes . . . Show slides and discuss charts with emphasis on importance of applied physics.

30 minutes . . . Mechanic in general (lecture demonstration, discussion).

30 minutes . . . Gas laws (Lecture demonstration, discussion).

30 minutes . . . Fluid flow (lecture demonstration, discussion).

240 minutes . . . Calculations and instruction sheets (written) Class activity (set up and operate experiments).

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

1) Beiser, Arthur, **Basic Concepts of Physics**, Reading, Mass.: Addison-Wesley Publishing Company, Inc., 1961.

INSTRUCTOR'S UNIT PLAN

Unit 15
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Pneumatic Pressure Sources**

AIM: To develop an understanding of basic pressure sources for pneumatic systems.

INSTRUCTIONAL AIDS:

Transparencies - Teacher-made; showing principles of pump operation.

Slides - **Pneumatic Pumps and Motors,** Cleveland, Ohio: Parker-Hannifin Corporation.

Wall Chart - **Compressed Air Power,** Cleveland, Ohio 44113: Compressed Air and Gas Institute, Room 1200-55 Public Square.

Cutaways of pumps.

EQUIPMENT:

Scott Educational System, Electromatic Pneumatic Trainer, 35 mm slide projector and screen.

PRIMARY REFERENCES:

1) **Compressed Air and Gas Handbook,** New York: Compressed Air and Gas Institute, 1970.

2) **Electromatic Manual for Pneumatics,** McMinnville, Tenn.: Electromatic Manufacturing Company, Inc., 1963.

3) **Fluid Power Handbook and Directory,** 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

4) Hedges, Charles S., **Industrial Fluid Power,** 2010 Shea Road, Dallas, Texas 75235: Womack Machine Supply Company, 1965-68.

I. INTRODUCTION and MOTIVATION

Show slide series and display wall charts and cutaways. Discuss with students the history of pneumatic compressors and distribution systems.

II. PRESENTATION of INTEGRATED CONCEPTS

	RELATED CONCEPTS	
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Positive displacement pump. 1. Characteristics	1. Delivers a fixed volume of air with each stroke. a. Dependent on pressure b. Dependnt on temperature 2. Medium on high pressure range. a. Medium pressure 1) 2 PSIG to 100 PSIG b. High pressure 1) Above 100 PSIG 3. Reciprocating pumps. a. Most common b. Uses a piston c. Valves 1) Finger 2) Feather 3) Plate 4) Rings d. Single stage or multiple stage 4. Power source. a. Electric motors b. Internal combustion engine c. Steam turbines	1. Study of atmospheric pressure and its effect on gauge pressure.
2. Piston displacement	1. Expressed in cubic feet per minute. 2. Equals net piston area x piston stroke. V x RPM 3. Volumetric efficiency. a. Capacity b. Equals $\frac{\text{delivered capacity}}{\text{Piston displacement}}$ 4. Air receiver a. Tank b. Stores air	
3. Compressor control	1. Manual control. a. Only stop and start b. Someone must depress the switch, watch the gauge until desired pressure is reached, and manually stop the compressor c. Not desirable d. Seldom used	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Formula for finding cubic inch displacement. V equals pie x r^2 x Stroke 2. Formula for finding volumetric efficiency. VE equals Delivered capacity / Positive displacement 3. Study of percentages. a. Changing percents to decimals b. Calculate percent of increase and decrease c. Calculate mechanical efficiency	1. Reading of gauges. 2. Abbreviations of terms. 3. The study and use of the USASI symbols.	1. The study of the history and development of pneumatic systems. 2. Importance to a military-industrial society.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
	2. Automatic shutoff. a. Compressor is set to run until the pressure reaches a maximum setting, then shuts off. When pressure falls below a minimum setting, compressor automatically starts, until the pressure again reaches the maximum setting. b. Desirable when compressor is required to run up to 50% of the time 3. Constant running. a. Continuous operation b. Unloading valve or relief valve used c. Desirable when compressor is required to run more than 50% of the time 4. Automatic start and stop or constant running. a. Combination of 2 and 3	
4. Intercoolers	1. Compression of air raises its temperature. 2. Air will expand. 3. Takes heat out of the air and prevents expansion of the air.	
B. Centrifugal pump. 1. Characteristics	1. Rotating. 2. Uses an impeller on a shaft. 3. Rotates at high velocity. 4. Creates pressure by means of centrifugal force. 5. Suction at outer edge of impeller.	1. Study of centrifugal force. 2. Applications of centrifugal . . . pumps.
2. Prime movers	1. Electric motor. 2. Internal combustion engine. 3. Steam turbine.	
3. Controls	1. Manual. 2. Automatic shutoff. 3. Constant running. 4. Automatic shutoff and constant running.	
4. Pressure development	1. Speed of rotation. 2. Design of impeller. 3. May be either single stage or multiple stage.	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES

III. APPLICATION

Students should complete laboratory assignment sheets concerning pneumatic pressure sources. Laboratory work should also be concerned with fabricating pneumatic distribution systems.

IV. EVALUATION CRITERIA GUIDELINE

A. What is meant by positive displacement?

B. What is centrifugal force?

C. What is an air receiver?

D. What is the purpose of an intercooler?

E. What is meant by volumetric efficiency?

V. SUMMARY

Air compressors are either of the positive displacement or the centrifugal type. Compressors must control the amount of pressure which is allowed to build up in the tank to avoid explosion. These safety valves may be either single stage or multiple stage.

VI. SUGGESTED TIME and SEQUENCE LISTING

60 minutes . . . Introduction.

120 minutes . . . Positive displacement theory.

150 minutes . . . Centrifugal theory.

30 minutes . . . Summary and evaluation.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

1) Barlow, Robert, **How to Pass High School Equivalency Examination: General Mathematical Ability**, New York: Cowles Educational Books, Inc., 1968.

INSTRUCTOR'S UNIT PLAN

Unit 16
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Pneumatic Cylinders**

AIM: To develop an understanding of the operation and application of pneumatic cylinders.

INSTRUCTIONAL AIDS:

Transparencies - Teacher-made; showing cylinder design and application.

Film - **Overworked and Underpowered.** Cleveland, Ohio 44113: Compressed Air and Gas Institute, Room 1200-55 Public Square (22 minutes, 16 mm).

Filmstrip - **Air Control Techniques.** Cleveland, Ohio: Parker Hannifin Corp.

EQUIPMENT:

Scott Engineering Educational System, Electromatic Pneumatic Trainer.

Filmstrip projector, 16 mm projector, 35 mm slide projector, record player and screen.

PRIMARY REFERENCES:

1) **Compressed Air and Gas Handbook.** New York: Compressed Air and Gas Institute, 1970.

2) **Electromatic Manual for Pneumatics,** McMinnville, Tenn.: Electromatic Manufacturing Company, Inc., 1963.

3) **Fluid Power Handbook and Directory,** 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

4) Hedges, Charles S., **Industrial Fluid Power,** 2010 Shea Road, Dallas, Texas 75235: Womack Machine Supply Company, 1965-68.

I. INTRODUCTION and MOTIVATION

Show students film and/or slides and discuss with them the operation and application of pneumatic cylinders.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Basic design.	1. Operation. a. Air pressure on one side of the piston causes the rod to move out of the other end of the cylinder provided the other end is vented b. Reversing the process returns the cylinder 2. Classifications. a. Rotating b. Non-rotating 3. Cushions. a. Purpose 1) Prevent damage by reducing excessive impact b. Types 1) Self-regulating 2) Adjustable 4. The operation of a cushion is when the vent port is partially closed and air pressure builds up between the piston and cylinder end causing a resistance to piston movement. 5. Mountings. a. Right angle base mount b. Clevis mount c. Right angle, flat base mount, blank end d. Right angle, flat base mount, rod end e. Parallel center line mount f. Trunnion mount 6. Single acting. a. Forced out by air pressure b. Returned by an external force c. Spring return . . . spring part of the cylinder 7. Double-acting. a. Forced out and in by air pressure 8. Others. a. Telescopic b. Hydro-check c. Rotating piston rods	1. Pascal's Law. 2. Boyle's Law. 3. Charles' Law.
B. Selection of cylinders.	1. Determine force. a. Desired pressure	

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TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Formula for determining force. F equals AP 2. Formula for finding the area of a circle. A equals Pi R_2 3. Formula for finding the volume of a cylinder. V equals Area x Stroke 4. Formula for finding acceleration. Fn equals Ma 5. Formula for finding velocity. V_f equals V_O plus AT V equals $\frac{S}{T}$ 6. Formula for finding volumetic rates.	1. The study of abbreviations for terms used in pneumatics. 2. The study of pneumatic symbology as set by the USASI.	1. The study of the history, development and use of pneumatic cylinders. 2. Search the patents pertinent to the invention and development of pneumatic cylinders.

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
	b. Desired size c. F equals AP (Force equals area x pressure) d. A equals piR^2 2. Mounting (previously described). 3. Maximum length. 4. Maximum air pressure. 5. Gas condition. 6. Ambient conditions. 7. Excessive temperatures. 8. Duty cycle. 9. Rod connection. a. Threaded b. Plain c. Clevis d. Others 10. Cylinder speed. a. Select size and diameter of cylinder b. Calculate mass of piston, piston rod, and load c. Assume kinetic frictional force of 1.5 for up to 3" cylinders d. Select a P_2 about 10 PSI below P_1 and calculate acceleration. From acceleration, determine time of complete stroke. Assume uniform acceleration and constant pressure P2 and calculate volumetric rate e. Select a solenoid valve size and calculate volumetric rate using P2 selected in stp d. If volumetric rates agree, the speed has been determined. 11. Guidelines. a. Valves should have as large an inner valve as practical b. Operating valves should be closed to the cylinder c. Air should be lubricated d. Pipelines should be large enough to prevent high pressure drops	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES

III. APPLICATION

Explain and demonstrate to the students the construction of the cylinder. Set up a pneumatic circuit using a cylinder and explain its operation and have students complete lab sheets.

IV. EVALUATION CRITERIA GUIDELINE

A. What are the two classifications of cylinders?

B. What is the purpose of cushions in cylinders?

C. Name three types of cylinder mountings.

D. What is a single-acting cylinder?

E. What is a double-acting cylinder?

V. SUMMARY

Air cylinders are used to perform various types of work, such as controlling industrial machines. The operation of a cylinder is simple enough; the air pressure on the bottom of the piston forces the piston to move. Cylinders are either single-acting (piston is only forced in one direction), or double-acting cylinder is forced in both directions). When selecting a cylinder, one should be concerned with the many variables that must be taken into account.

VI. SUGGESTED TIME and SEQUENCE LISTING

60 minutes . . . Introduction.

120 minutes . . . Basic design theory.

150 minutes . . . Cylinder selection theory.

30 minutes . . . Summary and evaluation.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

None deemed necessary other than primary.

INSTRUCTOR'S UNIT PLAN

Unit 17
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Pneumatic Valves**

AIM: To develop an understanding of the operation and application of pneumatic valves.

INSTRUCTIONAL AIDS:

Transparencies - teacher-made; showing valve circuitry and valve cutaways.

EQUIPMENT:

Scott Educational System, Electromatic Pneumatic Trainer, overhead projector and screen.

PRIMARY REFERENCES:

1) **Compressed Air and Gas Handbook.** New York: Compressed Air and Gas Institute, 1970.

2) **Electromatic Manual for Pneumatics.** McMinnville, Tenn.: Electromatic Manufacturing Company, Inc., 1963.

3) **Fluid Power Handbook and Directory.** 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

4) Hedges, Charles S., **Industrial Fluid Power.** 2010 Shea Road, Dallas Texas 75235: Womack Machine Supply Company, 1965-68.

I. INTRODUCTION and MOTIVATION

Present transparencies and cutaways to class. Set up and demonstrate various valve circuitry and explain their function in the circuit.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Introduction to valves.	1. Description. A restriction in a pipeline 2. Purpose. a. On or off b. Divert flow c. Adjust the flow 3. Types. a. Shut off b. Directional control c. Proportional 4. Selection. a. Type b. Operator c. Valve size d. Construction e. Mounting	1. Bernoulli's principle. 2. Fluids in motion a. Loss of pressure due to fluid friction b. Change in pressure due to change in fluid speed c. Transference of hydraulic energy of fluids to machines 1) Water wheels and turbines
B. Valve bodies.	1. Materials. a. Iron b. Brass c. Aluminum d. Stainless steel e. Chromium 2. Connections. a. Threaded NPT b. Soldered c. Flanged d. Welded 3. Mounting. a. Surface 1) Solid assemblies 2) Sub-plate assemblies b. In-line 4. Types. a. Gate b. Globe c. Needle d. Plug e. Butterfly	
C. Inner valves.	1. Styles. a. Gate b. Globe c. Needle d. Plug e. Butterfly f. Spool g. Slide	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Experiments and problem solving with fluids in motion. a. Pressure loss and pipe diameter b. Pressure-velocity problems	1. The study of the symbols set up by the USASI.	1. The study of the history development and use of valves in pneumatic circuits. 2. Chart the locations of ore deposits from which the metals used in valves originate. 3. List the valve uses in the forms of transportation used in moving these ores from mine to factory.

II. PRESENTATION of INTEGRATED CONCEPTS

INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	RELATED CONCEPTS: SCIENCE
	2. Two-way valves. a. Used for shutoff b. Used for proportioning flow c. Double ported 3. Three way. a. Used for directional control b. Two directions c. Seldom used for proportioning 4. Four-way. a. Used for directional control b. Two directions c. One neutral position	
D. Valve operators.	1. Mechanical. a. Cam b. Lever c. Acted upon by a machine 2. Manual. a. Cam b. Lever c. Button d. Acted upon by hand or foot 3. Electrical. a. Solenoid b. Electric motor 4. Pneumatic a. Cylinder b. Diaphragm 5. Hydraulic. a. Cylinders b. Diaphragms	
E. Valve sizing.	1. Shut off valves. a. Equal to line size 2. Operating a cylinder. a. Equal to cylinder port size b. If speed of cylinder is not important 3. When cylinder speed is critical. a. Establish maximum air flow b. Select directional to pass maximum flow at specified pressure drop	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES

III. APPLICATION

Students should design, fabricate and test various pneumatic circuits using a variety of valve combinations and arrangements.

IV. EVALUATION CRITERIA GUIDELINE

A. What are the three purposes of valves?

B. What materials are used for construction of valves?

C. What are the three types of valves?

D. List the operators of valves.

E. What is a four-way valve?

V. SUMMARY

Valves are used to control or direct airflow. In selecting a valve, one must take many things into account; such as valve type, operator, size, construction and mounting. Valves are usually constructed of metal, although synthetic materials are not uncommon. The main item to remember when selecting a valve is that one must always have the proper flow reaching the actuator.

VI. SUGGESTED TIME and SEQUENCE LISTING

30 minutes . . . Introduction.

60 minutes . . . General.

60 minutes . . . Valve bodies.

60 minutes . . . Inner valves.

60 minutes . . . Valve operators.

60 minutes . . . Valve sizing

30 minutes . . . Summary and evaluation.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

1) Stewart, Oscar, **Physics.** New York: Ginn and Company, 1950.

INSTRUCTOR'S UNIT PLAN

Unit 18
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Practical Application of Pneumatic Devices**

AIM: To develop an understanding of the application of pneumatic devices in industrial situations.

INSTRUCTIONAL AIDS:

Transparencies - Teacher-made; showing pneumatic circuitry.

Filmstrip and Record - **Pneumatic Circuitry,** Cleveland, Ohio: Parker-Hannifin Corporation.

Filmstrip and Record - **Preparing Air for Use.** Cleveland, Ohio: Parker-Hannifin Corporation.

EQUIPMENT:

Scott Engineering Educational System, Electromatic Pneumatic Trainer, filmstrip projector, record player, overhead projector and screen.

PRIMARY REFERENCES:

1) **Compressed Air and Gas Handbook.** New York: Compressed Air and Gas Institute, 1970.

2) **Electromatic Manual for Pneumatics.** McMinnville, Tenn.: Electromatic Manufacturing Company, Inc., 1963.

3) **Fluid Power Handbook and Directory,** 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

4) Hedges, Charles S., **Industrial Fluid Power,** 2010 Shea Road, Dallas, Texas 75235: Womack Machine Supply Company, 1965-68.

I. INTRODUCTION and MOTIVATION

Introduce pneumatic circuitry through filmstrips and transparencies. Explain the development of a circuit using the application requirements and demonstrate its operation on trainer.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Air . . . a motion medium.	1. Converging materials. a. Solids or liquids b. Dependability c. Low maintenance cost d. Elimination of spillage 2. Blending and mixing. a. Solids and liquids b. Floatation 3. Blowers, cooling and heating. a. Fans b. Air conditioning c. Heaters 4. Leak testing. a. Weldments b. Piping connections c. Hoses d. Pressure vessels 5. Blast cleaning. a. Sandblasting b. Gritblasting 6. Underwater operations. a. When electricity cannot be used 7. Air curtains. 8. Air tools. a. Paving breakers b. Clay diggers c. Backfill tampers d. Sumps and sludge pumps e. Surface grinders f. Chipping hammers g. Others	1. The study of centrifugal and centripetal forces. a. Circular motion b. Centripetal acceleration c. Laws of motion 2. Application and demonstrations of foregoing principles. a. Cream separators, dryers, b. Experiments phonographs 1) Weights on a string 2) Cars on a track
B. Air motors.	1. Vane type. a. Blades b. Rotor c. Types 1) Reversing 2) Non-reversing d. Low or medium power requirements e. Lightweight f. Used for hand tools 2. Piston type. a. Used for high power b. Radial c. Axial	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Problems involving force calculations. a. Centripetal force b. Centrifugal force c. Vectors	1. The study of symbology for the various terms.	1. The study of the history, development and use of various pneumatic components. 2. Importance of pneumatic tools in transportation system, e.g., constructing highways connecting remote cities.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
C. Characteristics of air motors.	1. Explosive proof. a. Used highly explosive materials 2. Will not be damaged by stall or overload. 3. Will withstand extreme heat. 4. Easily obtain variable speed. 5. Easily reversible. 6. Compact and lightweight. 7. Greater safety.	
D. Maintenance of air motors and tools.	1. Preventative. a. Proper lubrication b. Replacing worn parts immediately c. Removing moisture from lines 2. Scheduled maintenance. a. Daily b. Weekly c. Monthly d. Yearly 3. Emergency. a. Whenever needed	
E. Safety.	1. Cannot be overemphasized. 2. For instance, a 6 inch grinding wheel turning at 6,000 RPM's has a surface speed of 107 miles per hour.	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES

III. APPLICATION

Students should design pneumatic circuits and set them up for demonstration on the trainer.

IV. EVALUATION CRITERIA GUIDELINE

A. Design two basic pneumatic circuits.

B. Name two classifications of air motors.

C. Name five characteristics of air motors.

D. Describe the types of maintenance that are required for air motors.

V. SUMMARY

Pneumatic devices are used to perform many types of useful work. The type of work may be anywhere from conveying work from one place to another, to an air curtain. Air motors are the most common devices used. Air motors can be used to do almost any work that can be done by an electric motor.

VI. SUGGESTED TIME and SEQUENCE LISTING

30 minutes . . . Introduction.

90 minutes . . . A motion medium.

60 minutes . . . Air motors.

60 minutes . . . Characteristics.

60 minutes . . . Maintenance.

30 minutes . . . Safety.

30 minutes . . . Summary and evaluation.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

1) Beiser, Arthur, **Basics Concepts of Physics**, Reading, Mass.: Addison-Wesley Publishing Company, Inc., 1961.

INSTRUCTOR'S UNIT PLAN

Unit 19
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Pneumatic Directional Control Devices**

AIM: To develop an understanding of the operation and application of pneumatic control devices.

INSTRUCTIONAL AIDS:

Transparencies - Teacher-made; showing the application of pneumatic directional control valves.

Slides - **Directional Control Valves.** Manchester, Mich.: Double A Products Company.

EQUIPMENT:

Scott Engineering Educational System, Electromatic Pneumatic Trainer, overhead projector, slide projector and screen.

PRIMARY REFERENCES:

1) **Compressed Air and Gas Handbook.** New York: Compressed Air and Gas Institute, 1970.

2) **Electromatic Manual for Pneumatics,** McMinnville, Tenn.: Electromatic Manufacturing Company, Inc., 1963.

3) **Fluid Power Handbook and Directory.** 812 Huron Road, Cleveland, Ohio: Industrial Publishing Corporation, 1970-71.

4) Hedges, Charles S., **Industrial Fluid Power,** 2010 Shea Road, Dallas, Texas 75235: Womack Machine Supply Company, 1965-68.

I. INTRODUCTION and MOTIVATION

Introduce topic with slide and transparencies. Demonstrate to class basic pneumatic circuit designs using directional control valves and the circuit applications.

II. PRESENTATION of INTEGRATED CONCEPTS

INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	RELATED CONCEPTS: SCIENCE
A. Two-way valves.	1. General shutoff application. 2. Seldom used to operate cylinders. 3. A single-acting cylinder would require 2 two-way valves. 4. A double-acting cylinder would require 4 two-way valves.	
B. Three-way valves.	1. Generally used to operate a single acting cylinder. 2. Two directions. 3. Three connections. 4. A double acting cylinder would require 2 three-way valves.	
C. Four-way valves (4 ports).	1. Generally used to operate a double acting cylinder. 2. Two positions. 3. Two directions. 4. Four connections. 5. Operators. a. Manual b. Mechanical c. Electrical d. Pneumatic e. Hydraulic	
D. Four-way valves (5 ports).	1. Generally used to operate a double acting cylinder. 2. Two positions. 3. Two directions. 4. Five connections. 5. Independent exhaust port.	
E. Three position valves.	1. Generally used to operate a double acting cylinder when it is desirable to stop the cylinder midway. 2. Neutral positions. 3. Two directions. 4. Four or more connections. 5. More expensive.	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
	1. Study of the symbology used with pneumatic devices set up by the USASI.	1. The study of the history, development and use of pneumatic devices. 2. Graph the extent of usage of pneumatic devices among various major industries.

III. APPLICATION

Students should design and set up a variety of pneumatic circuits using directional control valves.

IV. EVALUATION CRITERIA GUIDELINE

A. What is a 2-way valve used for?

B. What is a 3-way valve used for?

C. What is a 4-way valve used for?

D. What is the purpose of a three-position valve?

V. SUMMARY

In order to use pneumatic control to do useful work, it is necessary to control airflow. The airflow must be controlled to operate cylinders, motors and other actuators. There are many types of valves with a variety of applications. In order to successfully design a pneumatic circuit, one must have an in-depth understanding of directional control valves.

VI. SUGGESTED TIME and SEQUENCE LISTING

30 minutes . . . Introduction.

60 minutes . . . Two-way valves.

60 minutes . . . Three-way valves.

90 minutes . . . Four-way 4 ports.

60 minutes . . . Four-way 5 ports.

60 minutes . . . Three-position valves.

30 minutes . . . Summary and evaluation.

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

None deemed necessary other than primary.

INSTRUCTOR'S UNIT PLAN

Unit 20
Lesson 1
Time . . . . . 6 hours

CLUSTER: TRANSPORTATION

DIVISION: FLUID POWER

SUBJECT: **Fluidics (Fluid Amplifiers)**

AIM: To acquaint the student with the basic application of fluid amplifiers and their principles of operation.

INSTRUCTIONAL AIDS:

Transparencies - Teacher-made; showing the principles of fluid amplifier operation and their application.

EQUIPMENT:

Fluidics panelboard and components, Electromatic Pneumatic Trainer, overhead projector and screen.

PRIMARY REFERENCES:

1) **Fluidic Systems Design Guide,** 6300 West Havard Street, Chicago, Ill. 60648: Imperial-Eastoman Corporation.

2) Kirshner, Joseph M., **Fluid Amplifiers,** New York: McGraw-Hill Book Company, Inc., 1966.

3) **Studies of Reattaching Jet Flows in Fluid State Wall Attachment Devices,** - AD623911, 5285 Port Royal Road, Springfield, Va. 22151: Department of Commerce, Clearinghouse for Federal Scientific and Technical Information, Sills Building.

4) **Use of Hydraulic Analogy in Study of Fluid Interaction Devices** - AD405867, 5285 Port Royal Road, Springfield, Va. 22151: Department of Commerce, Clearinghouse for Federal Scientific and Technical Information, Sills Building.

I. INTRODUCTION and MOTIVATION

Explanation and demonstrate principles of an amplifier. Present and discuss the wall effect, stream interaction and vortex principles.

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
A. Amplifier functions.	1. Amplify. a. If a small signal of unit 1, when increased to unit 2, can cause another signal of unit 100 to increase to 200, then it has been amplified	1. *All principles* of amplifiers will be explained and demonstrated with physics lab equipment incorporated on pneumatic (fluidic) panel . . . boards
B. Amplifier principles.	1. Wall effect. a. Wall effect, also called the Coanda effect, is the natural attachment of a free jet to an adjacent wall b. Air, when entering a narrow confined area, will oscillate until it touches one wall. The air will then stay at that wall because of the low pressure developed between nozzle and wall. 2. Stream interaction. a. Basis for proportional amplifiers. b. Use of an input signal between two control ducts. Increasing or decreasing one of the control ducts will cause the main inlet stream to split and move to one output, thus increasing the output by a small change on the control ducts. 3. Turbulence amplifiers. a. If the pressure from the supply tube is increased, the turbulence area will form in front of the output tube and the pressure to the output tube will decrease	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES
1. Mathematical calculations.	1. Reading manometers. 2. Setting pressure regulators and reading pressure gauges. 3. Designing fluidic circuits to perform specific applications.	1. Historical development from air pneumatics to modern aerospace applications of fluidics. Also the digit computers affect change of industrial use and new frontiers developed. 2. Importance of fluid amplifiers to development of polar and tropical regions due to adaptability to high and low temperatures. 3. Improved safety conditions resulting from reduced electrical hazards.

		RELATED CONCEPTS
INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE
	4. Double-leg elbow amplifier. a. The flow from the power duct is through the active and passive legs. Force is exerted on the active leg by the passive leg to cause a "bending" effect of the fluid. Thus causing main flow to move to the other duct by just applying a small signal change in the control duct. 5. Direct impact modulator. a. This device can be used with high impedance control and output ducts and allows for connection of several devices. Fluid analog computers utilize this principle. 6. Vortex amplifier. a. Is a proportional amplifier and is comparable to a variable resistor in electricity b. When air is applied from the control inlet duct, it causes a spiraling effect in the power stream, and the spiraling effect increases the velocity of the power stream due to the conversion of angular momentum. This has the effect of blocking the output and sufficient control pressure, the power flow will approach zero.	
C. Types of amplifiers.	1. Flip-flop unit. a. Actually a switch that flips from one output port to the other upon receiving its signal from the control inlet, when a predetermined pressure has been reached. 2. Memory unit. a. Is designed to operate by a command from the flip-flop and will retain its position until another signal is received.	

TO BE DEVELOPED

MATH	COMMUNICATIONS	SOCIAL STUDIES

II. PRESENTATION of INTEGRATED CONCEPTS

		RELATED CONCEPTS
TECHNICAL CONCEPTS	INSTRUCTIONAL TOPICS	SCIENCE
D. Advantages of fluidics.	1. Works well in high energy radiation fields. 2. They have long life and reliability due to "no moving parts." 3. They are not affected by high (1400°F) or low temperatures sub-zero). 4. Limitations are only those of the material from which they are made. 5. Safe operation as they eliminate electrical hazards.	
E. Disadvantages of fluidics.	1. Slow speed in movement compared with electricity. 2. Stand-by power consumption (constant flow and high volume consumed).	

TO BE DEVELOPED

INSTRUCTIONAL TOPICS	TECHNICAL CONCEPTS	SCIENCE

III. APPLICATION

Present the various units which are available and their general applications such as switch, proportional amplifier, memory and flow resistor. Discuss the characteristics of fluid devices relative to their advantages and disadvantages when compared to electric circuits. Students should set up basic fluidics circuits.

IV. EVALUATION CRITERIA GUIDELINE

A. What is a fluid amplifier?

B. Name two types of fluid amplifiers which are used as flow restrictors.

C. Which of the three principles of fluid amplifiers is the basis for the proportional amplifiers

D. Which fluid amplifier principle is used for memory amplifier units?

V. SUMMARY

The functional application of fluid amplifiers has a tremendous impact on pneumatic instrumentation and controls. They have application in high radiation fields and have long life and reliability due to the fact they have no moving parts. They also eliminate electrical hazards, and are not affected by high and low temperatures.

VI. SUGGESTED TIME and SEQUENCE LISTING

30 minutes . . . Show transparencies; discussion of "Fluidics".

60 minutes . . . Amplifiers . . . functions and principles.

60 minutes . . . Types and applications of amplifiers.

30 minutes . . . Advantages and disadvantages.

180 minutes . . . Instruction sheet: class activity on fluidic panelboards (used on trainer).

VII. SUPPLEMENTAL REFERENCES and RESOURCE MATERIAL

1) Giles, R. V., **Outline of Theory and Problems of Fluid Mechanics and Hydraulics.** New York: Schaum Publishing Company, Inc., 1962.

2) Pease, Dudley A., **Basic Fluid Power,** Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1967.

3) Rutkowski, Joseph (ed.), "Fluidics," **Bendix Technical Journal,** 1:4, Winter, 1969.

4) Stewart, Harry L. and Storer, John M., **Fluid Power,** Indianapolis, Ind.: The Howard W. Sams Company, Inc., 1968.

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